US007072476B2

(12) **United States Patent**
White et al.

(10) **Patent No.: US 7,072,476 B2**

(45) **Date of Patent: Jul. 4, 2006**

(54) **AUDIO HEADSET**

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(73) Assignee: **Matech, Inc.**, Portland, OR (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 284 days.

(21) Appl. No.: **10/342,102**

(22) Filed: **Jan. 13, 2003**

(65) **Prior Publication Data**

US 2004/0136543 A1 Jul. 15, 2004

Related U.S. Application Data

(63) Continuation of application No. PCT/US01/22121, filed on Jul. 13, 2001, which is a continuation-in-part of application No. 09/878,151, filed on Jun. 7, 2001, now abandoned, and a continuation-in-part of application No. 09/615,168, filed on Jul. 13, 2000, now abandoned, which is a continuation-in-part of application No. 08/989,816, filed on Dec. 12, 1997, now Pat. No. 6,370,245, which is a continuation-in-part of application No. 08/801,525, filed on Feb. 18, 1997, now Pat. No. 5,907,538.

(60) Provisional application No. 60/265,988, filed on Feb. 2, 2001, provisional application No. 60/230,217, filed on Sep. 5, 2000, provisional application No. 60/228,129, filed on Aug. 25, 2000, provisional application No. 60/223,291, filed on Aug. 3, 2000.

(51) **Int. Cl.**
H04R 1/10 (2006.01)

(52) **U.S. Cl.** **381/74**; 381/328; 381/71.1; 370/276

(58) **Field of Classification Search** 381/74; 379/406.08; 370/276
See application file for complete search history.

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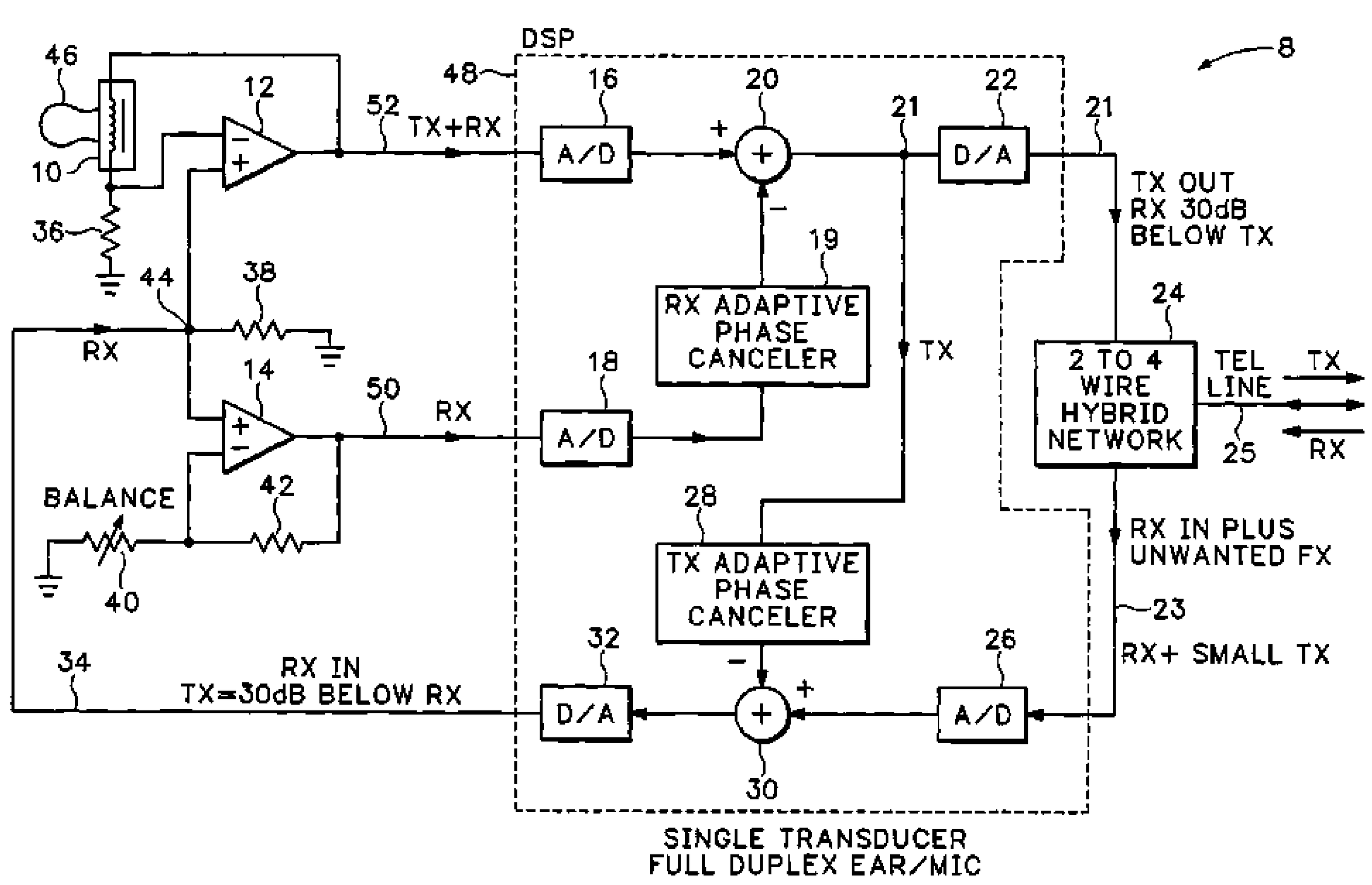
Primary Examiner—Huyen Le
Assistant Examiner—Con P. Tran
(74) *Attorney, Agent, or Firm*—Marger Johnson & McCollom, P.C.

(57) **ABSTRACT**

A headset includes two earpieces. One earpiece acts as a microphone, and the other earpiece acts as an earphone. Isolated from background noise and vibrations due to bone conduction, the microphone earpieces convert voice sounds from the air column in the external ear canal into electrical signals. Other embodiments of the invention address feedback problems and achieve improved performance relative to existing full duplex communication devices. In another embodiment of the invention a headset includes a band having opposite ends that extend in a forward direction from the two earpieces. The band then either extends downwardly or backwards.

17 Claims, 23 Drawing Sheets



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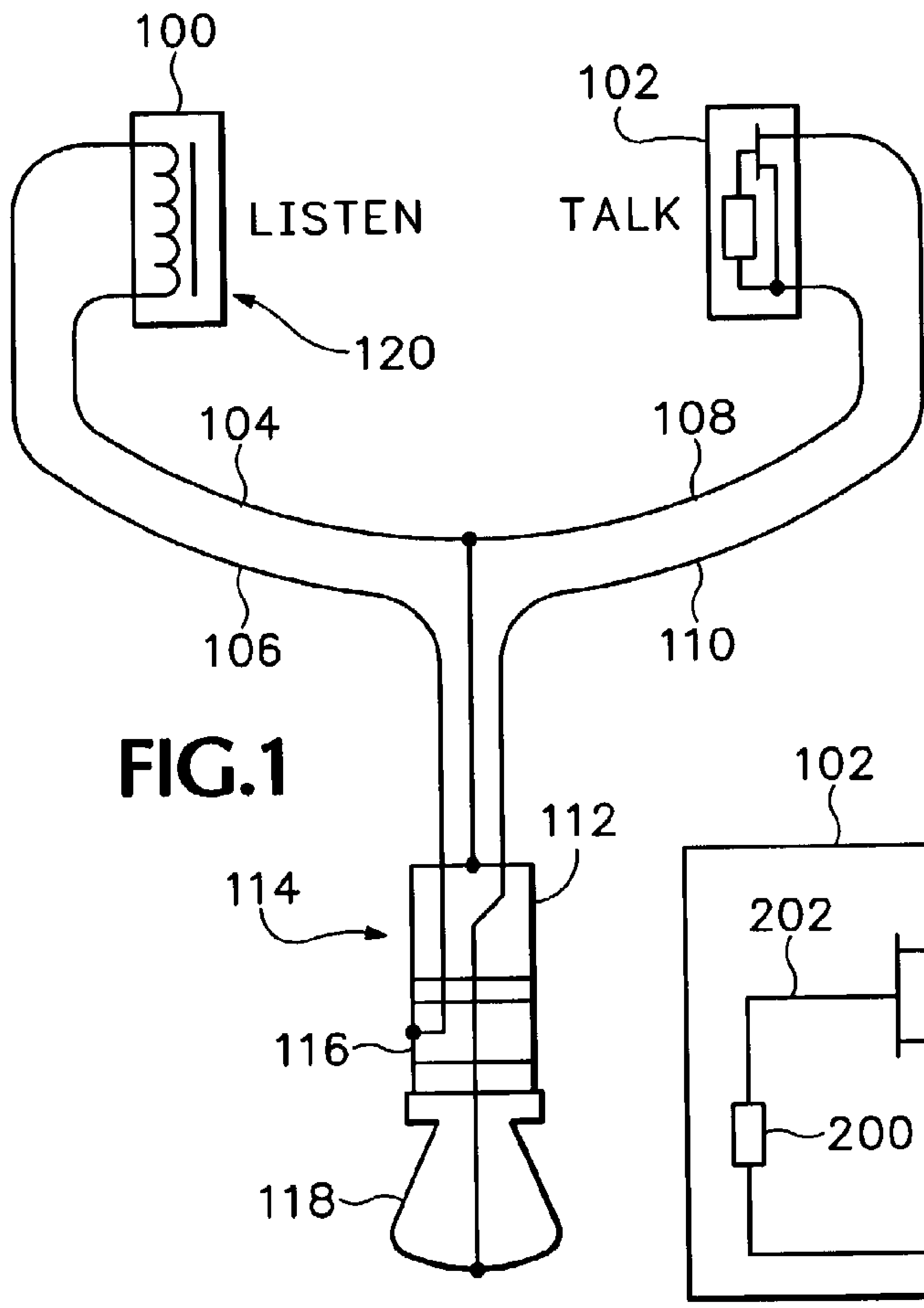


FIG.1

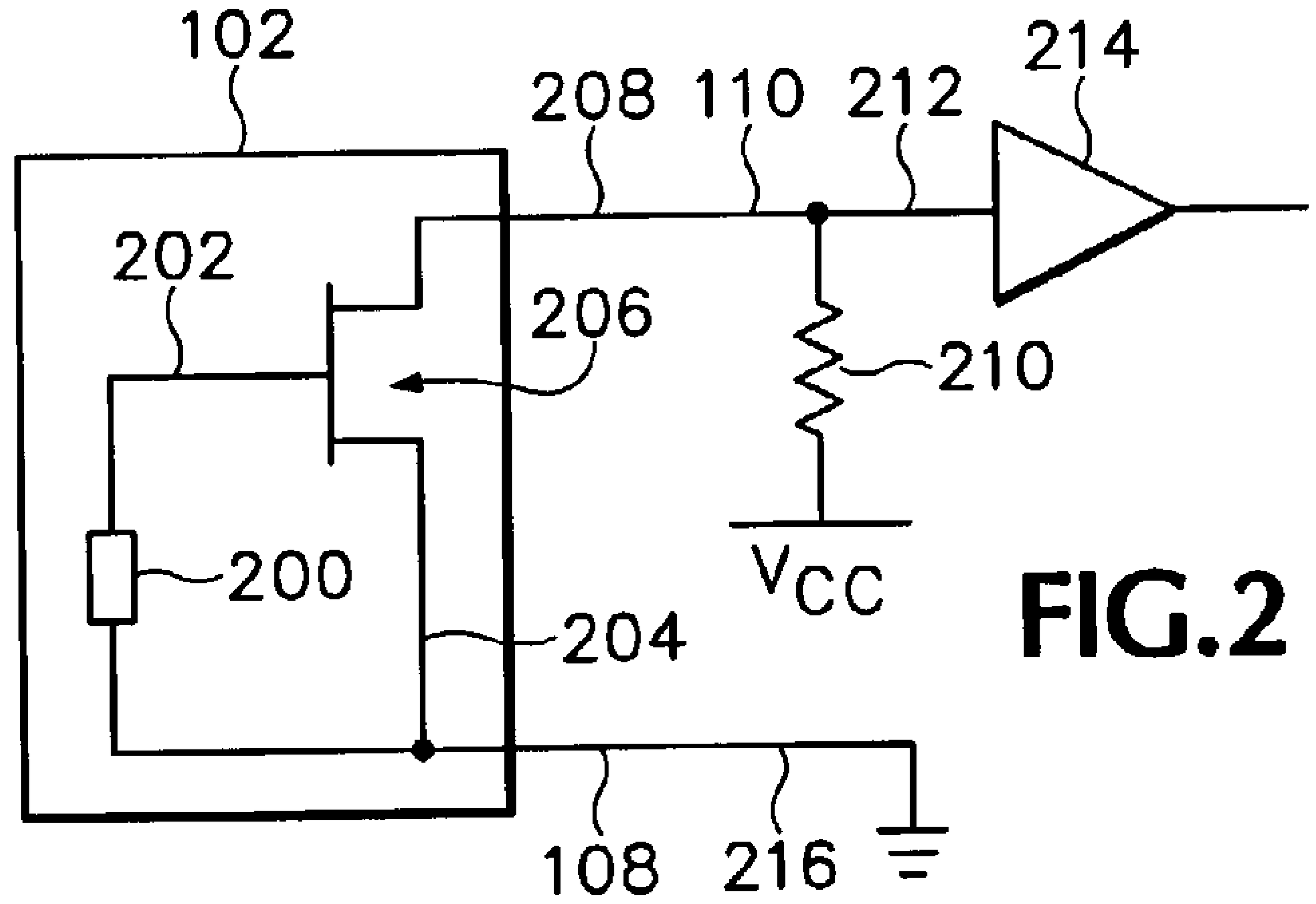


FIG.2

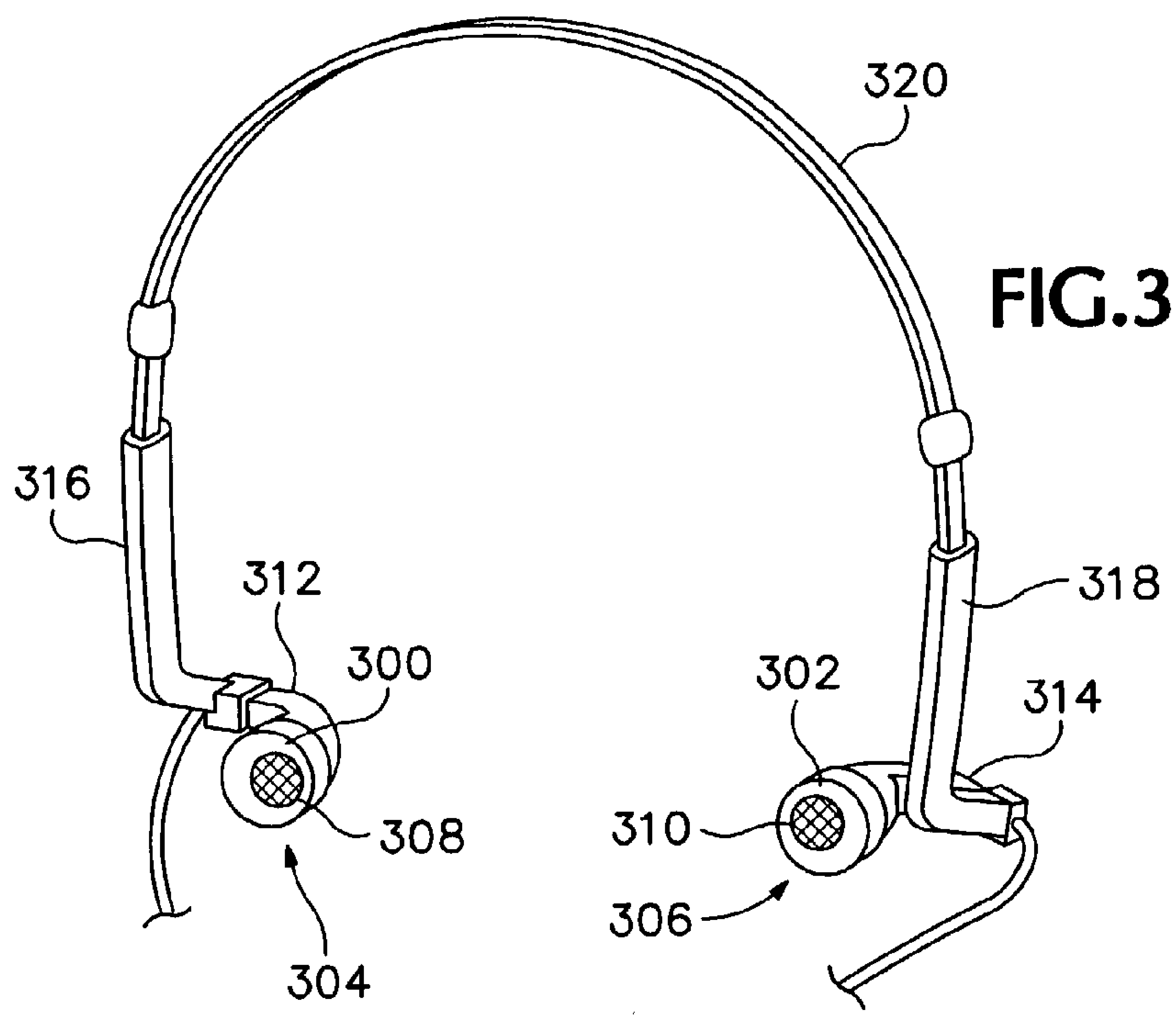


FIG.3

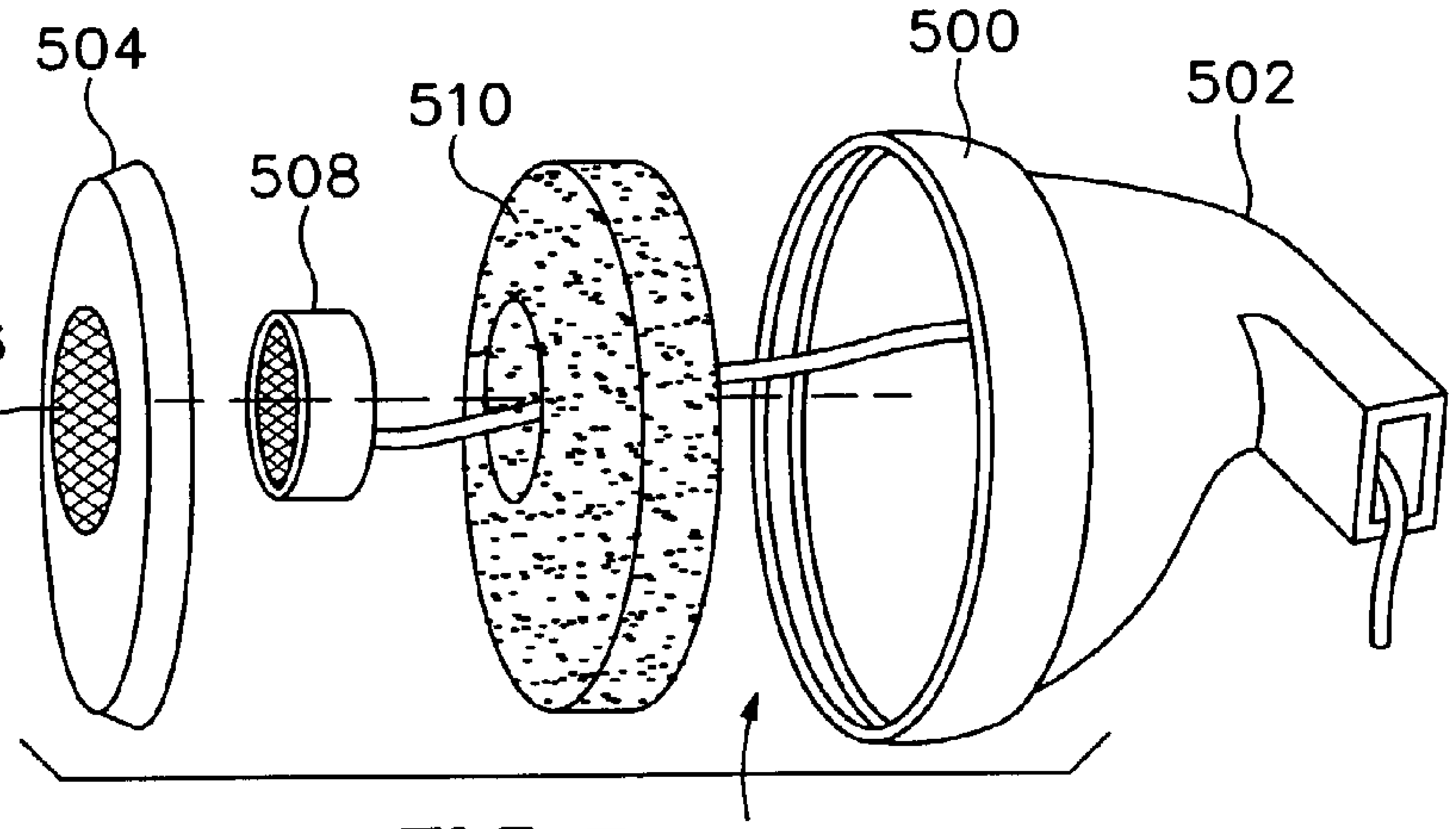


FIG.5

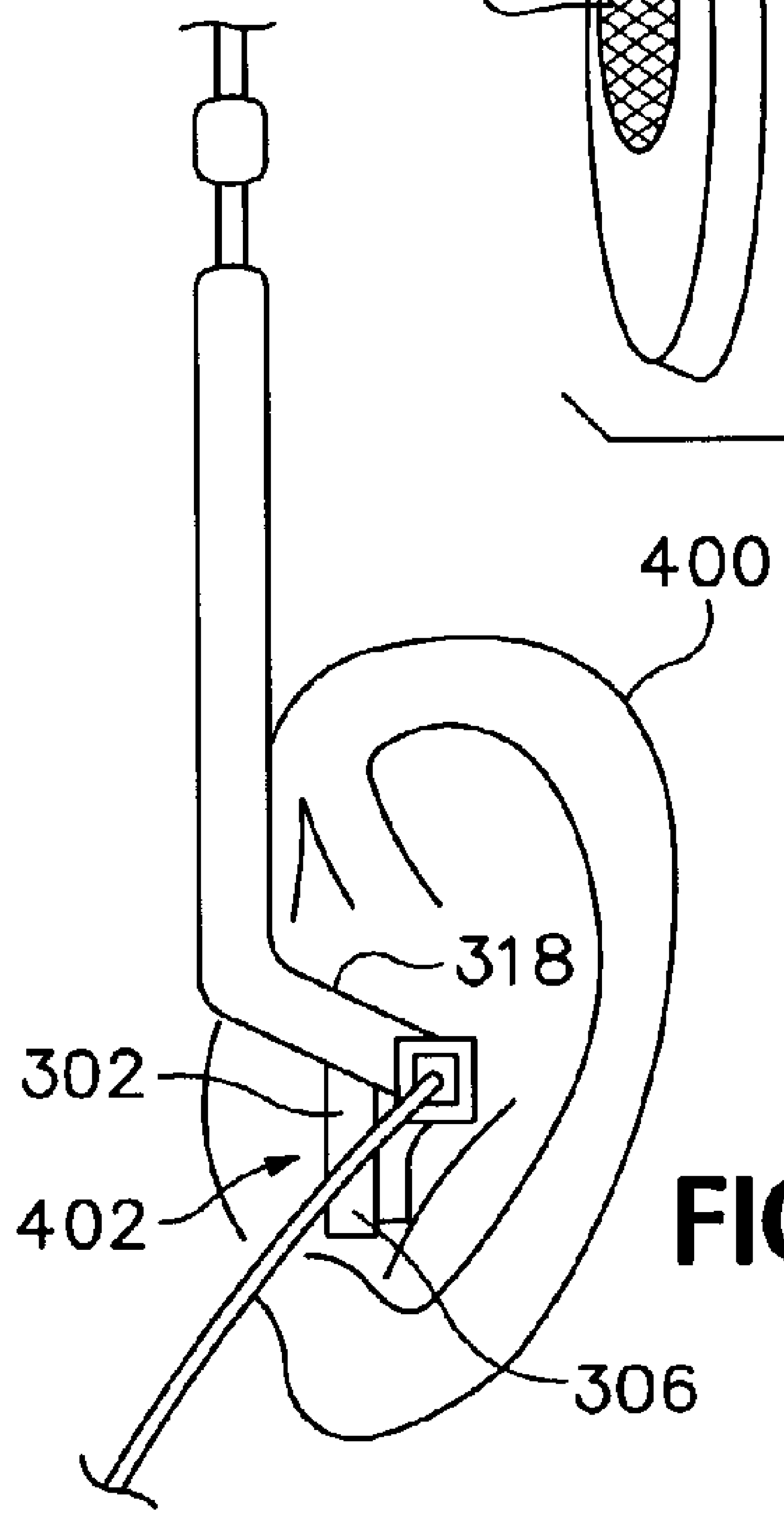


FIG.4

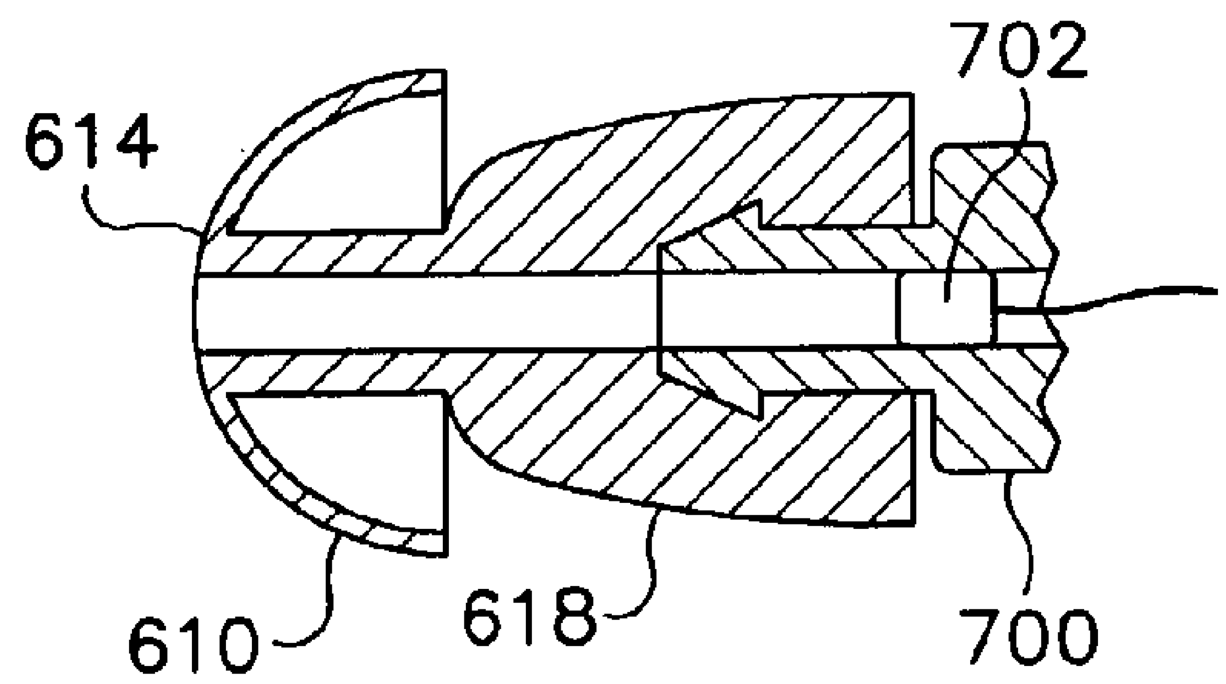


FIG.7

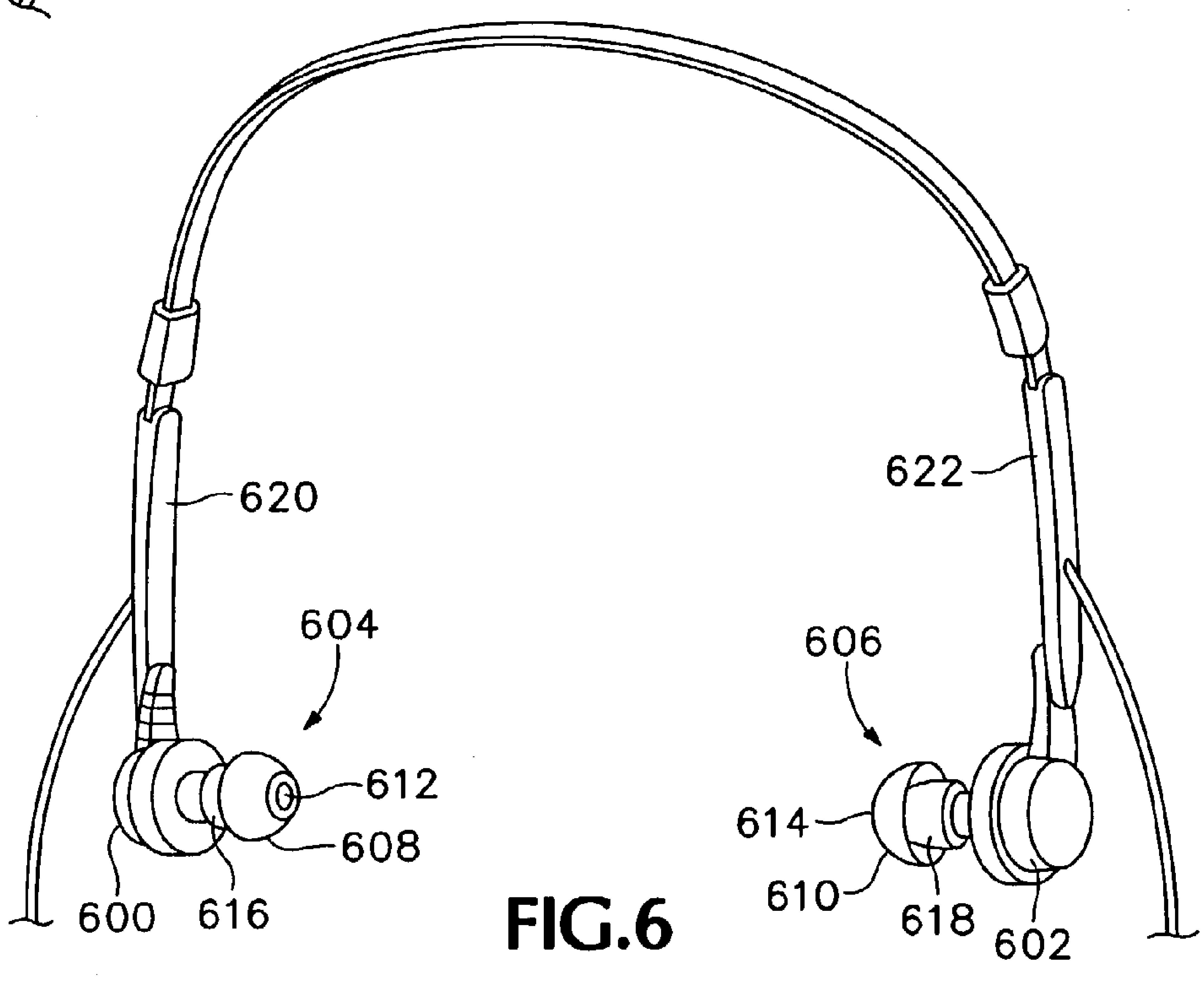
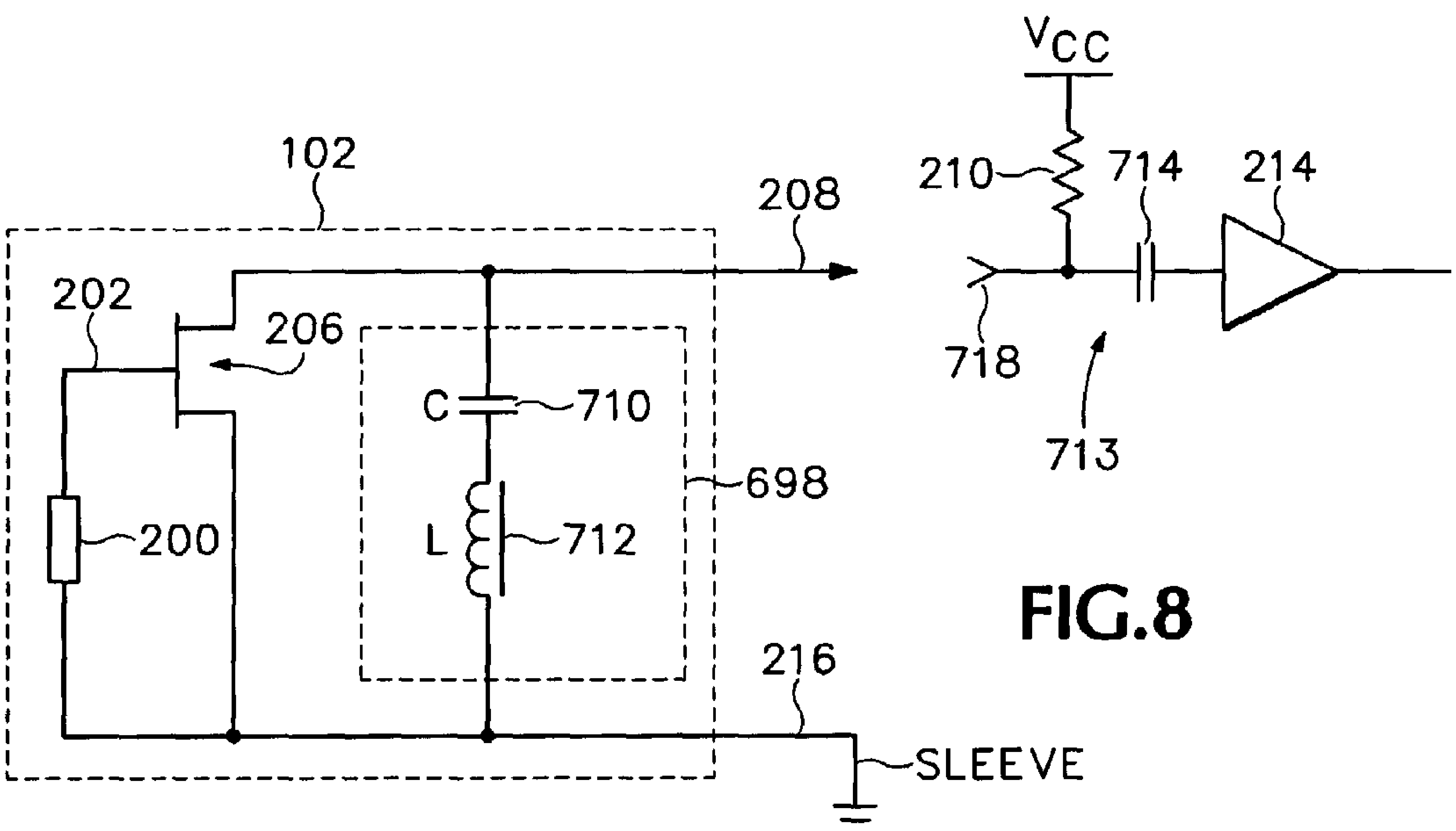
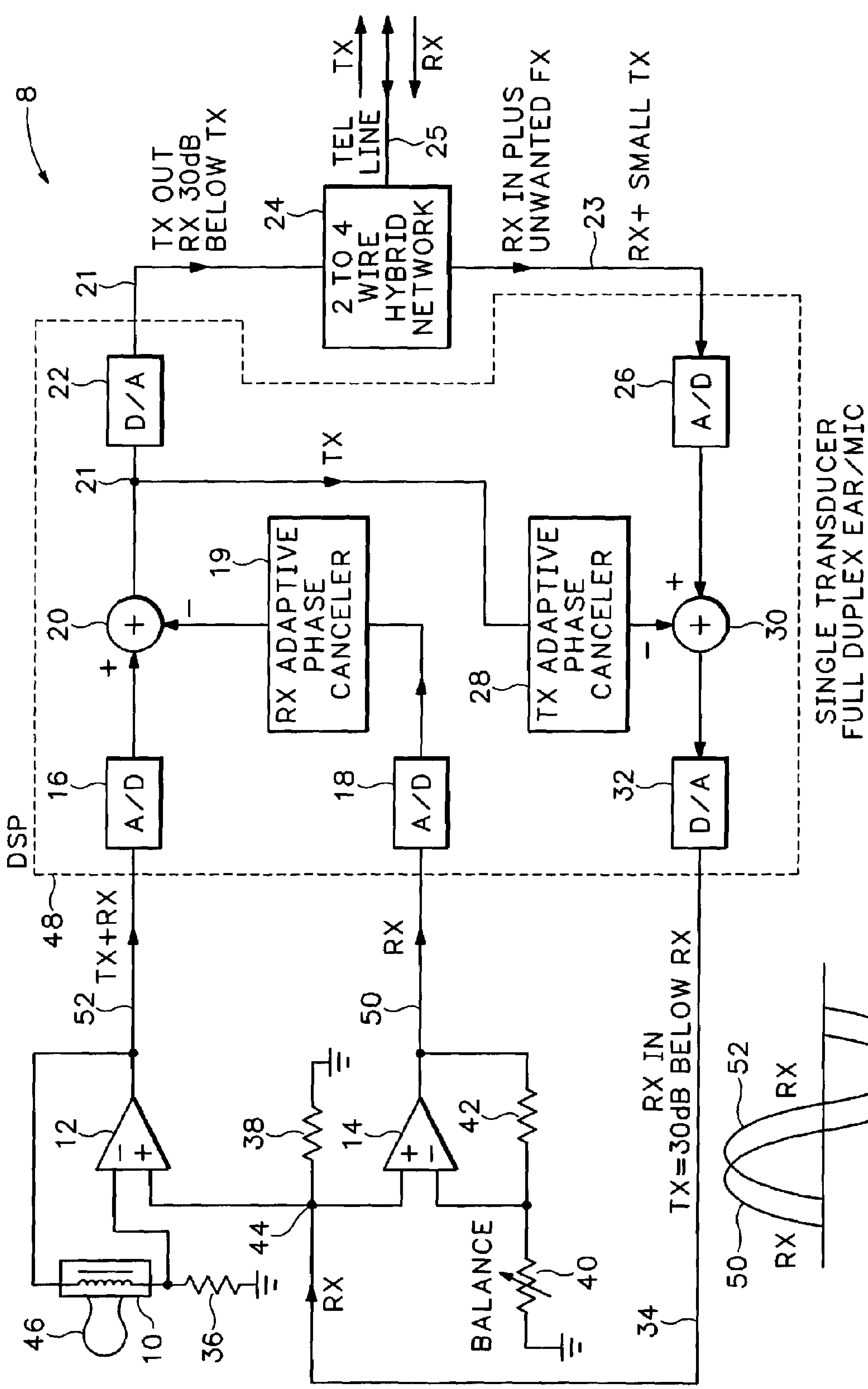


FIG.6



VCC
102
208
210
714
214
202
206
718
C
710
713
698
200
L
712
216
SLEEVE

FIG.8


8
TX OUT
RX 30dB
BELOW TX
TEL
LINE
TX
RX
25
24
2 TO 4
WIRE
HYBRID
NETWORK
RX IN PLUS
UNWANTED FX
23
RX+ SMALL TX
21
22
D/A
26
A/D
21
TX
19
RX ADAPTIVE
PHASE
CANCELER
28
TX ADAPTIVE
PHASE
CANCELER
20
30
16
A/D
18
A/D
32
D/A
DSP
48
TX+RX
52
RX
50
12
14
38
42
44
RX
BALANCE
40
46
10
36
34
RX IN
TX=30dB BELOW RX
SINGLE TRANSDUCER
FULL DUPLEX EAR/MIC
52
RX
50
RX
FIG.9
FIG.10

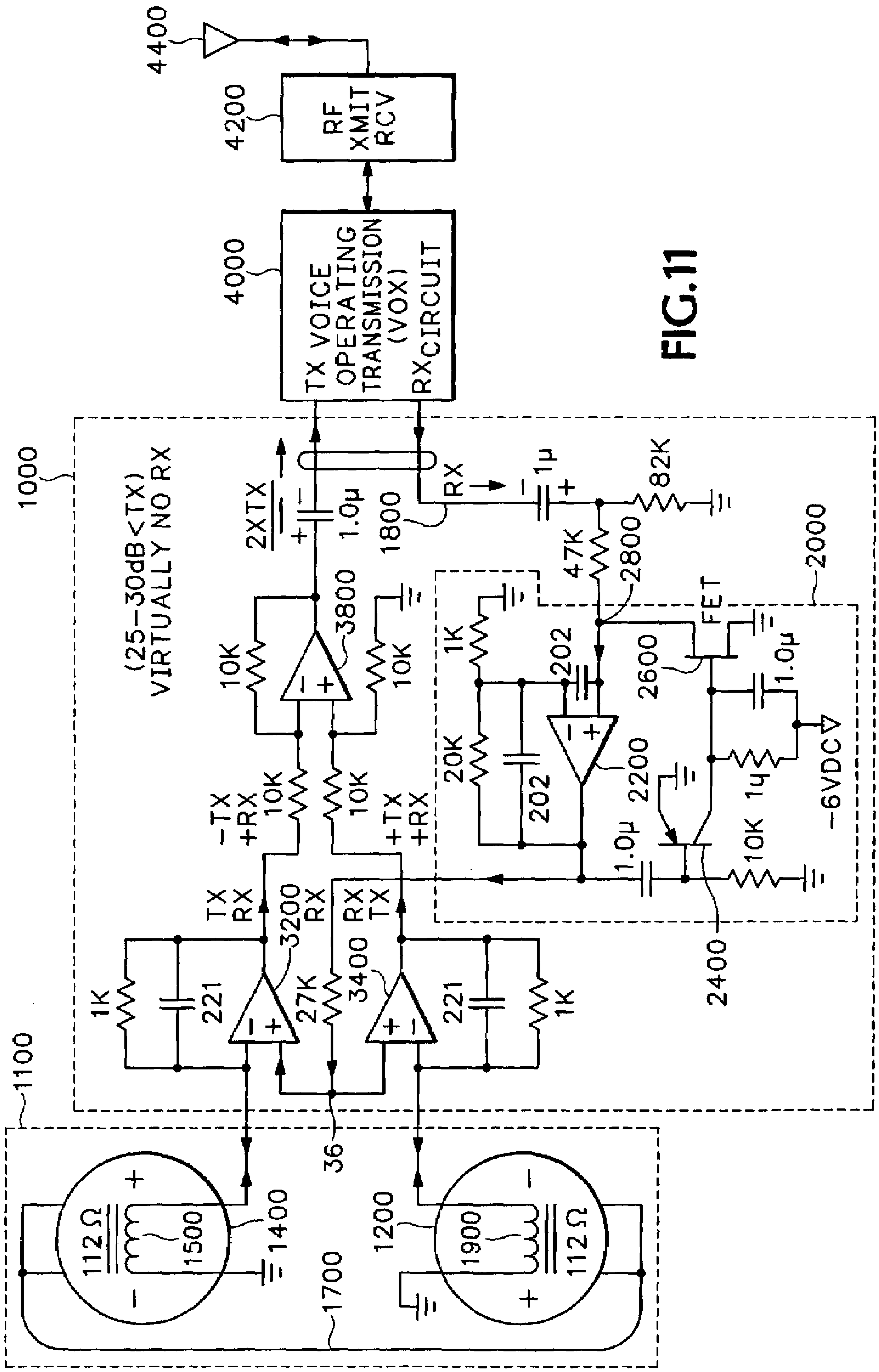

4400
4200
RF
XMIT
RCV
4000
TX VOICE
OPERATING
TRANSMISSION
(VOX)
RX CIRCUIT
1000
(25–30dB<TX)
VIRTUALLY NO RX
2XTX
1.0μ
1800
RX
1μ
82K
47K
2800
2000
FET
2600
1.0μ
1K
202
20K
202
2200
1μ
−6VDC
10K
1.0μ
2400
10K
3800
−TX
+RX
+TX
+RX
TX
RX
3200
RX
RX
TX
3400
27K
1K
221
1100
36
112Ω
1500
1400
1200
1900
1700

FIG.11

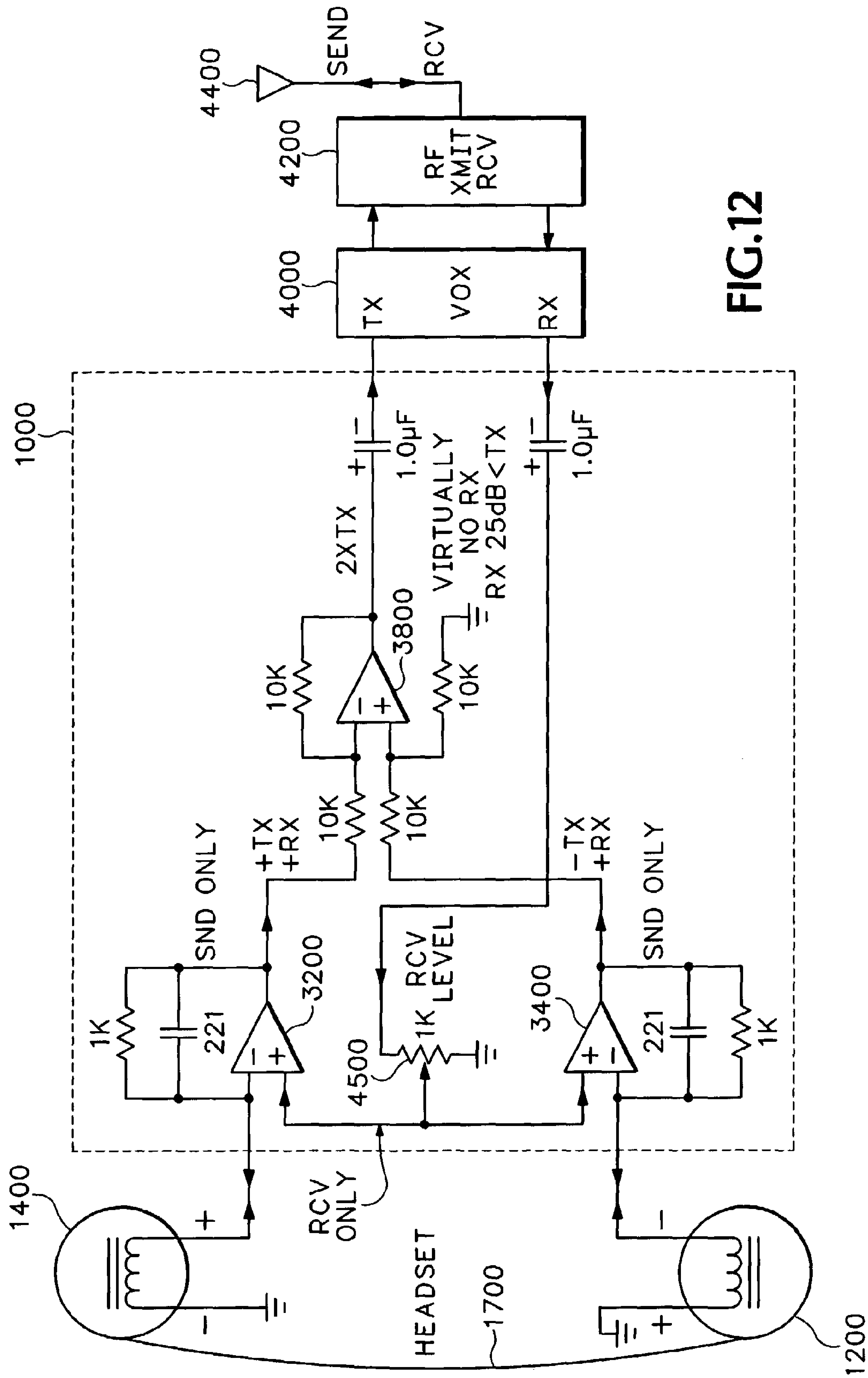

4400
SEND
RCV
4200
RF
XMIT
RCV
4000
TX
VOX
RX
1000
1.0μF
1.0μF
2XTX
VIRTUALLY
NO RX
RX 25dB<TX
3800
10K
10K
10K
10K
SND ONLY
+TX
+RX
-TX
+RX
SND ONLY
3200
1K
221
RCV
LEVEL
4500
1K
3400
221
1K
1400
RCV
ONLY
HEADSET
1700
1200

FIG.12

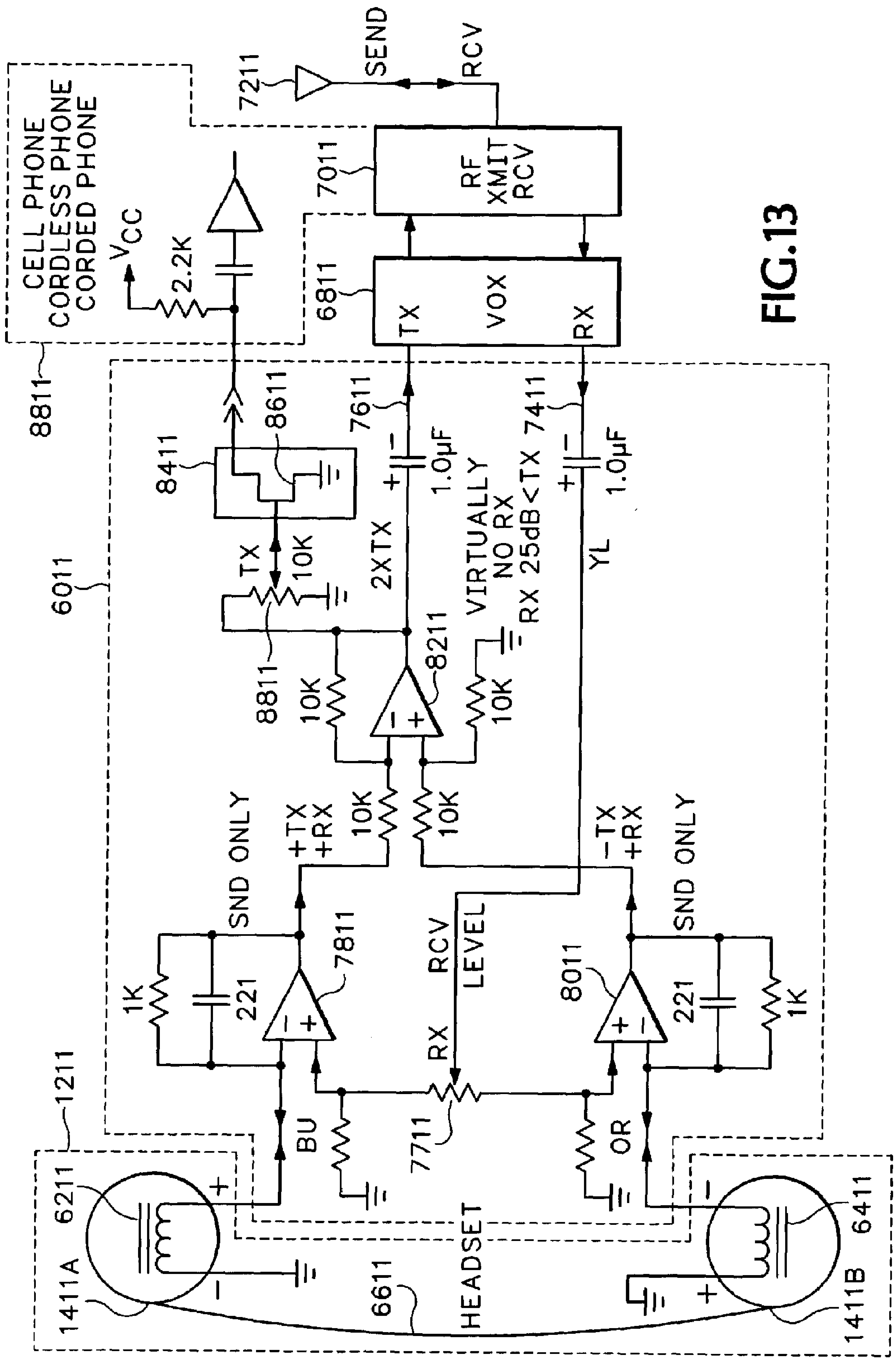
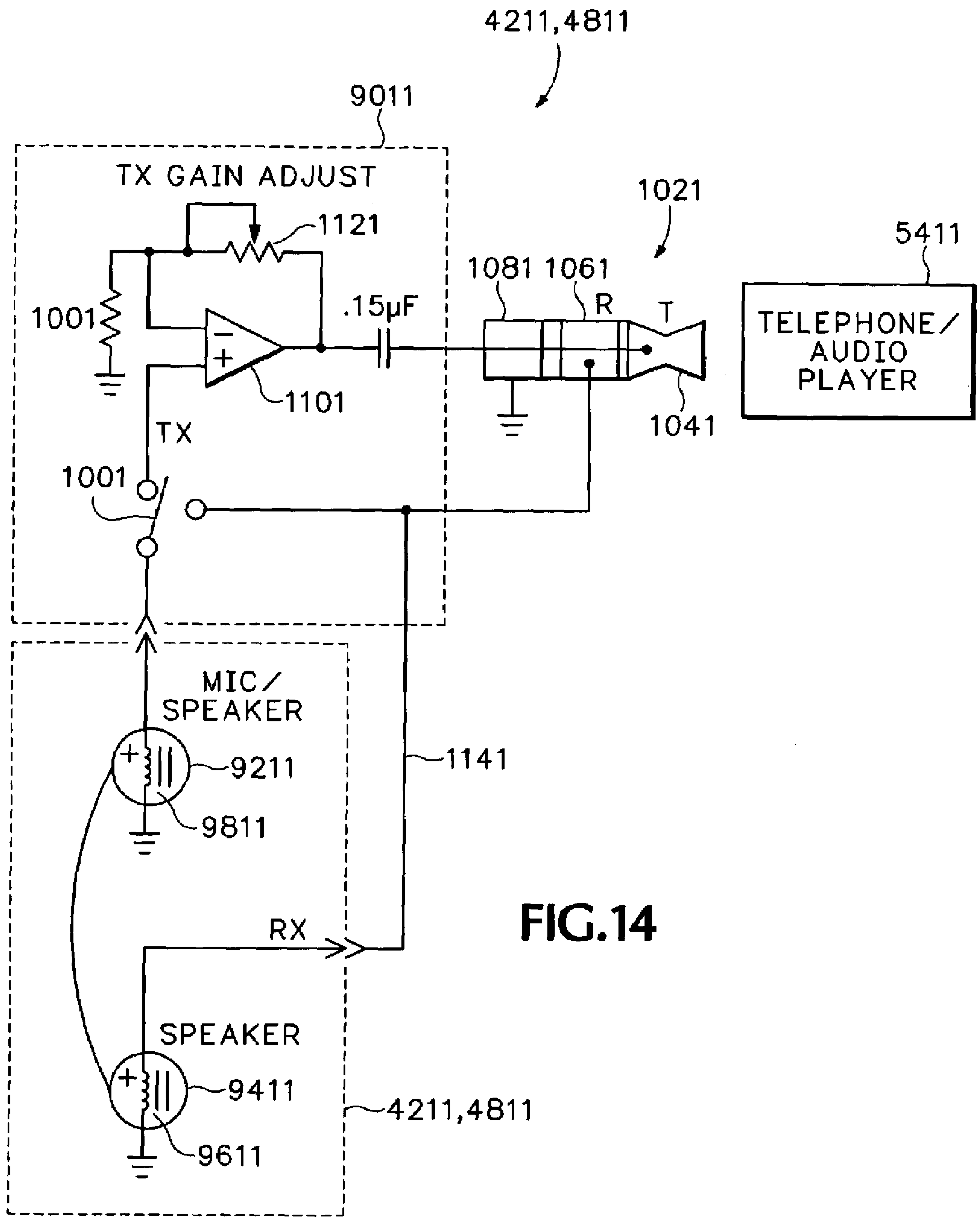

CELL PHONE
CORDLESS PHONE
CORDED PHONE
V_{CC}
2.2K
8811
7211
SEND
RCV
7011
RF
XMIT
RCV
6811
TX
VOX
RX
6011
8411
8611
TX
10K
7611
1.0μF
2XTX
VIRTUALLY
NO RX
RX 25dB<TX
7411
YL
8811
10K
8211
SND ONLY
+TX
+RX
−TX
+RX
1K
221
7811
8011
RCV
LEVEL
RX
7711
BU
OR
1211
6211
6411
1411A
1411B
6611
HEADSET

FIG.13



4211,4811
9011
TX GAIN ADJUST
1121
1001
.15µF
1101
TX
1001
1021
1081 1061
R
T
1041
5411
TELEPHONE/
AUDIO
PLAYER
MIC/
SPEAKER
9211
9811
1141
RX
SPEAKER
9411
9611
4211,4811

FIG.14

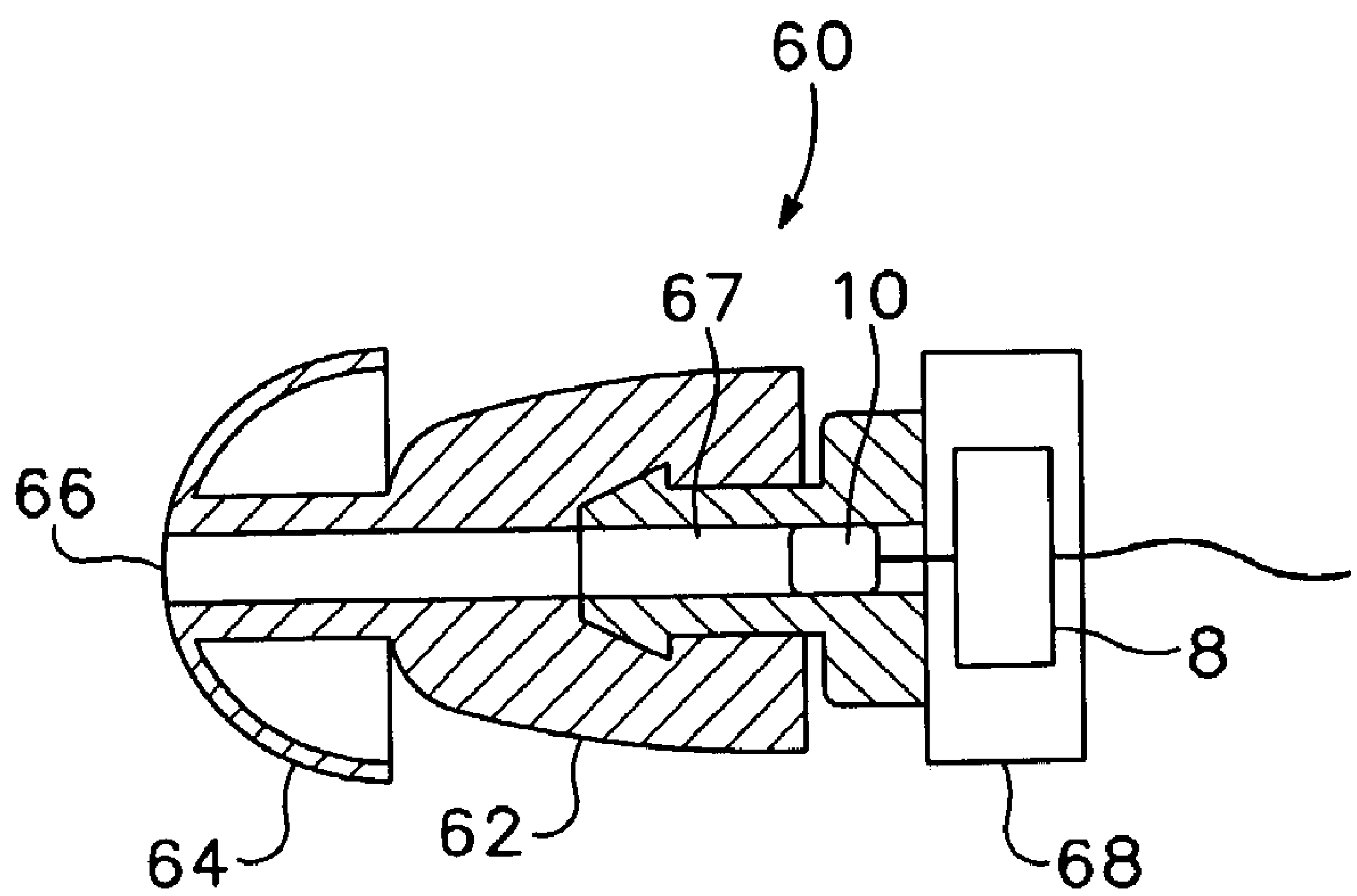


FIG.15

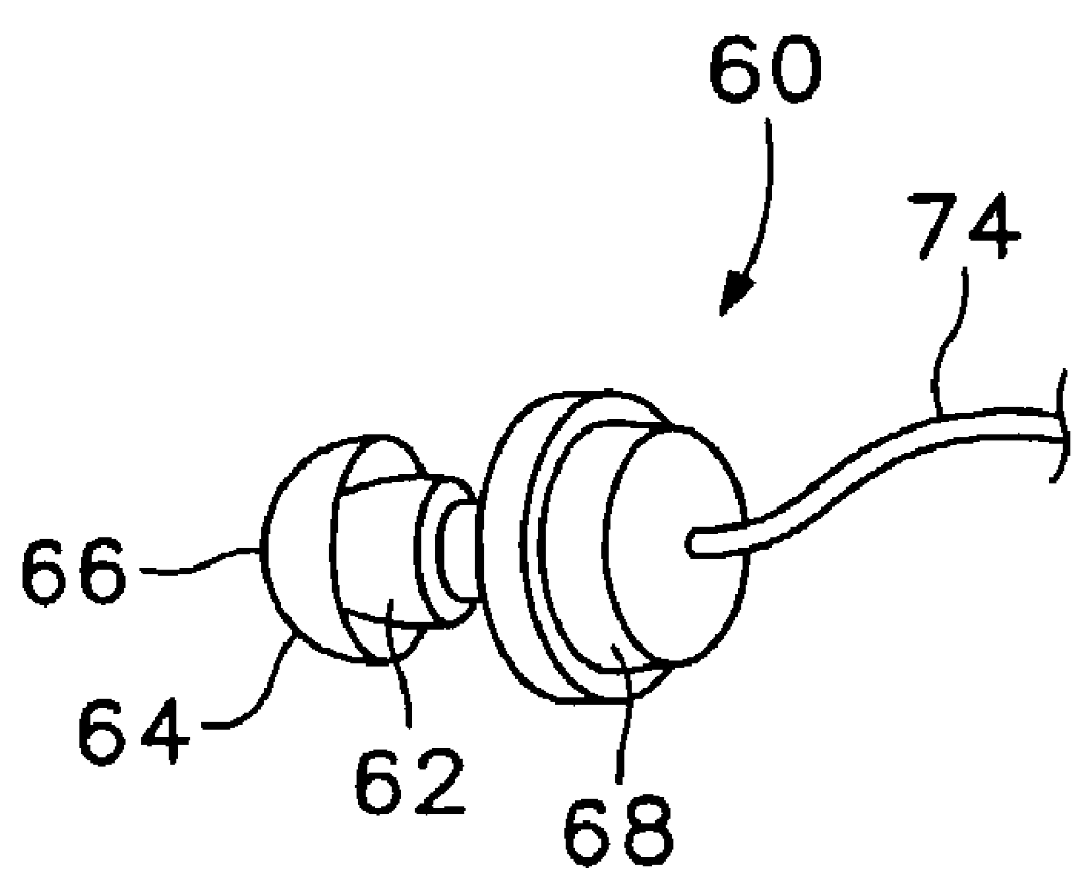


FIG.16

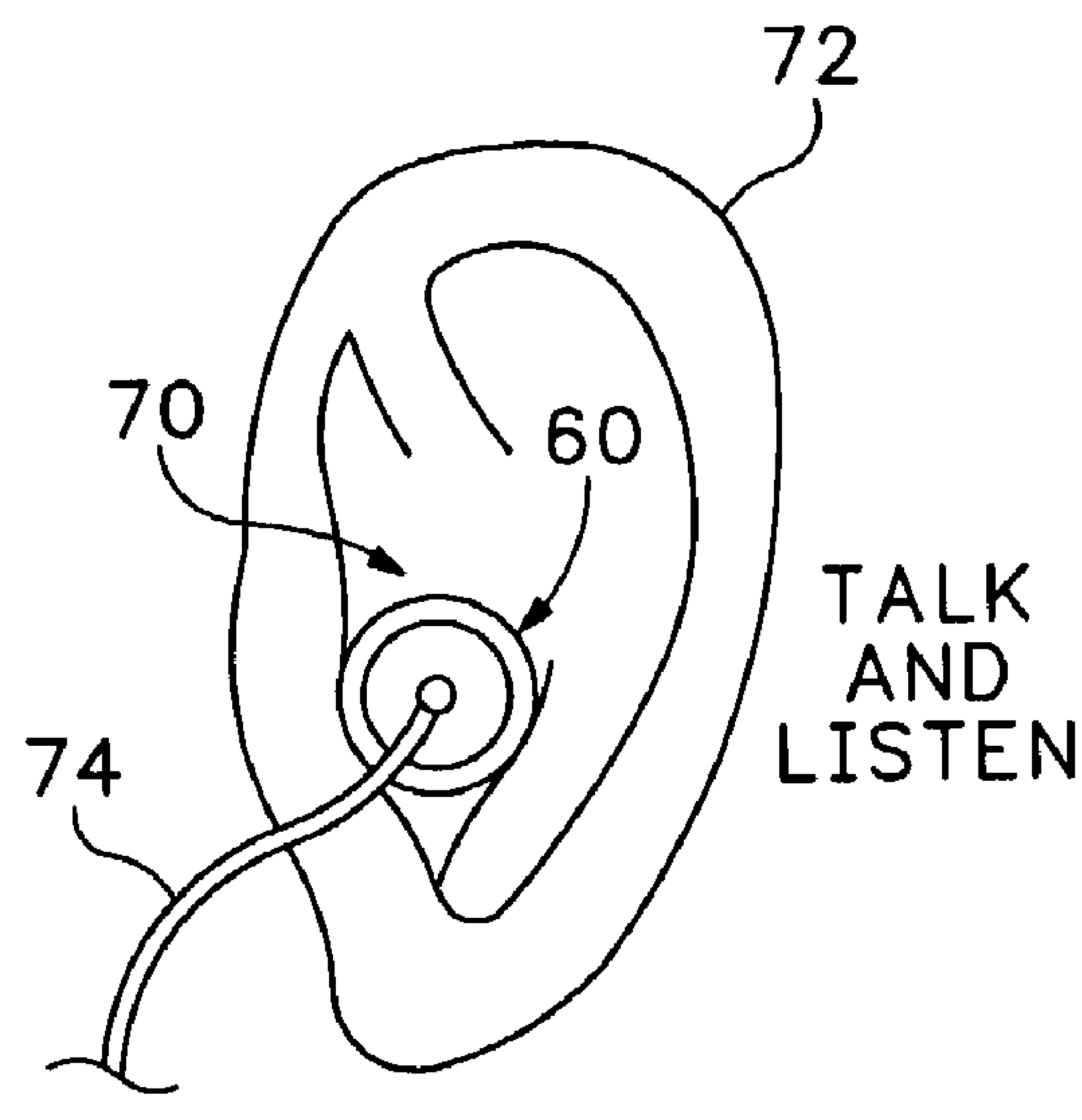


FIG.17

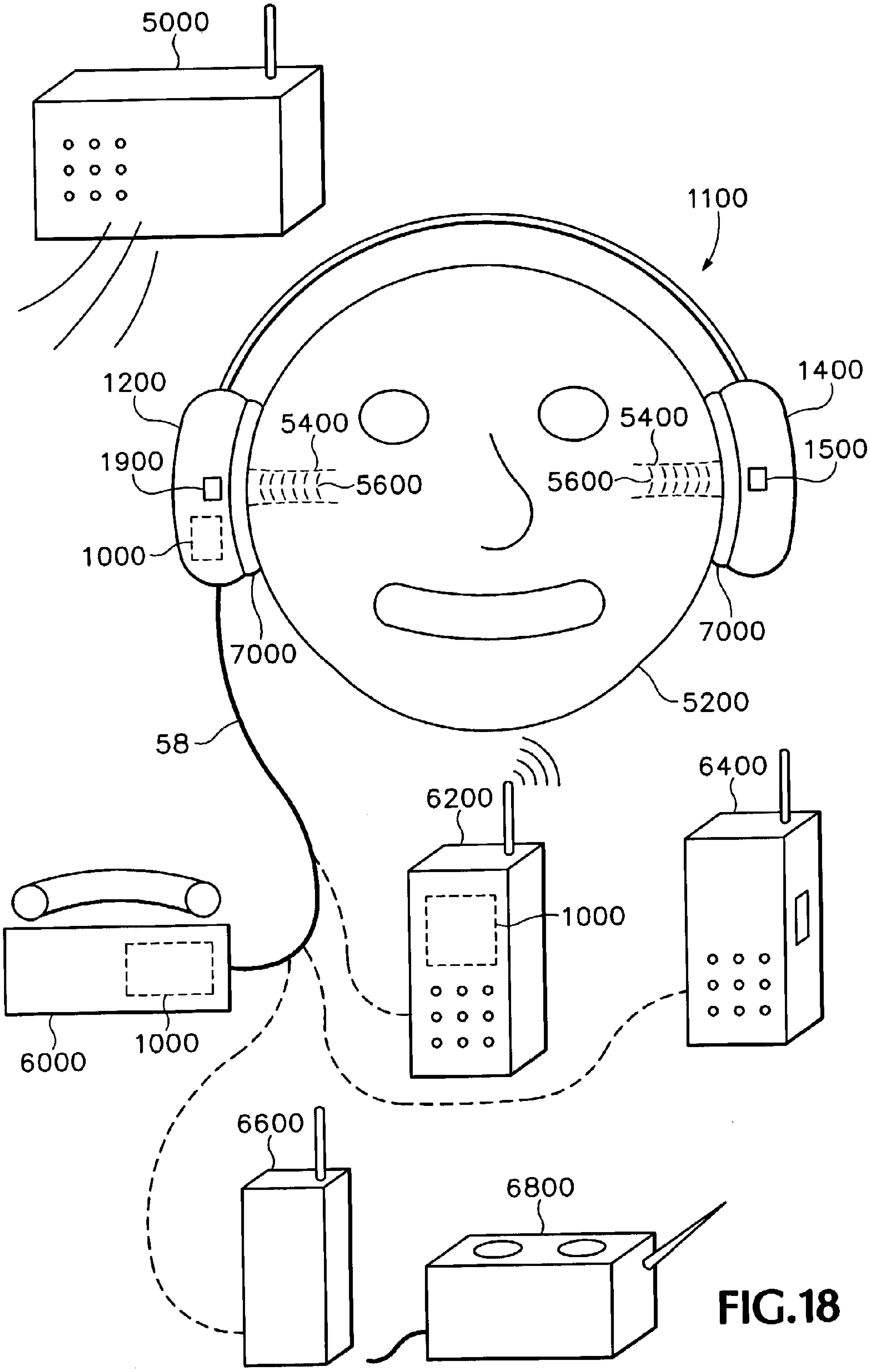
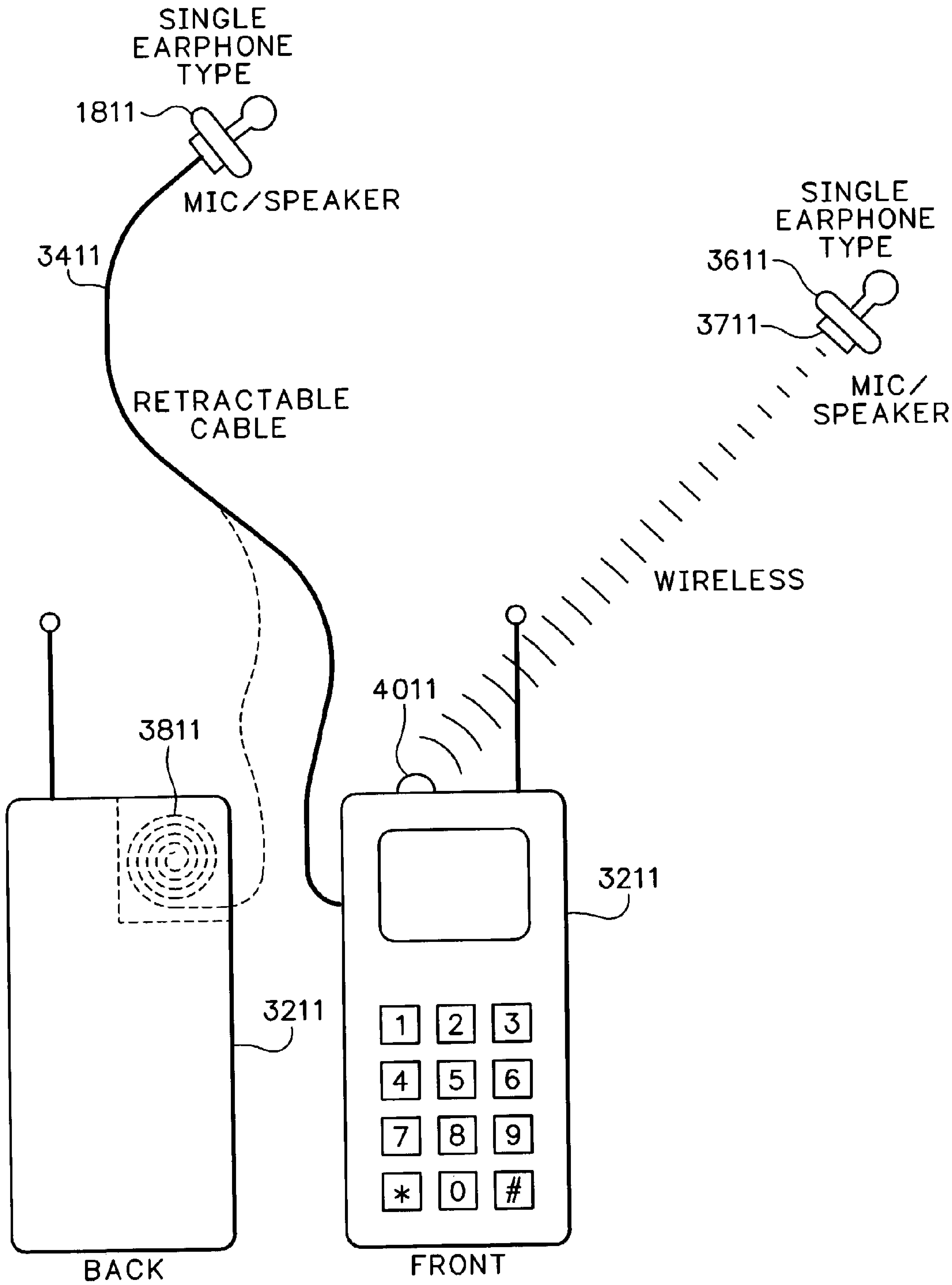
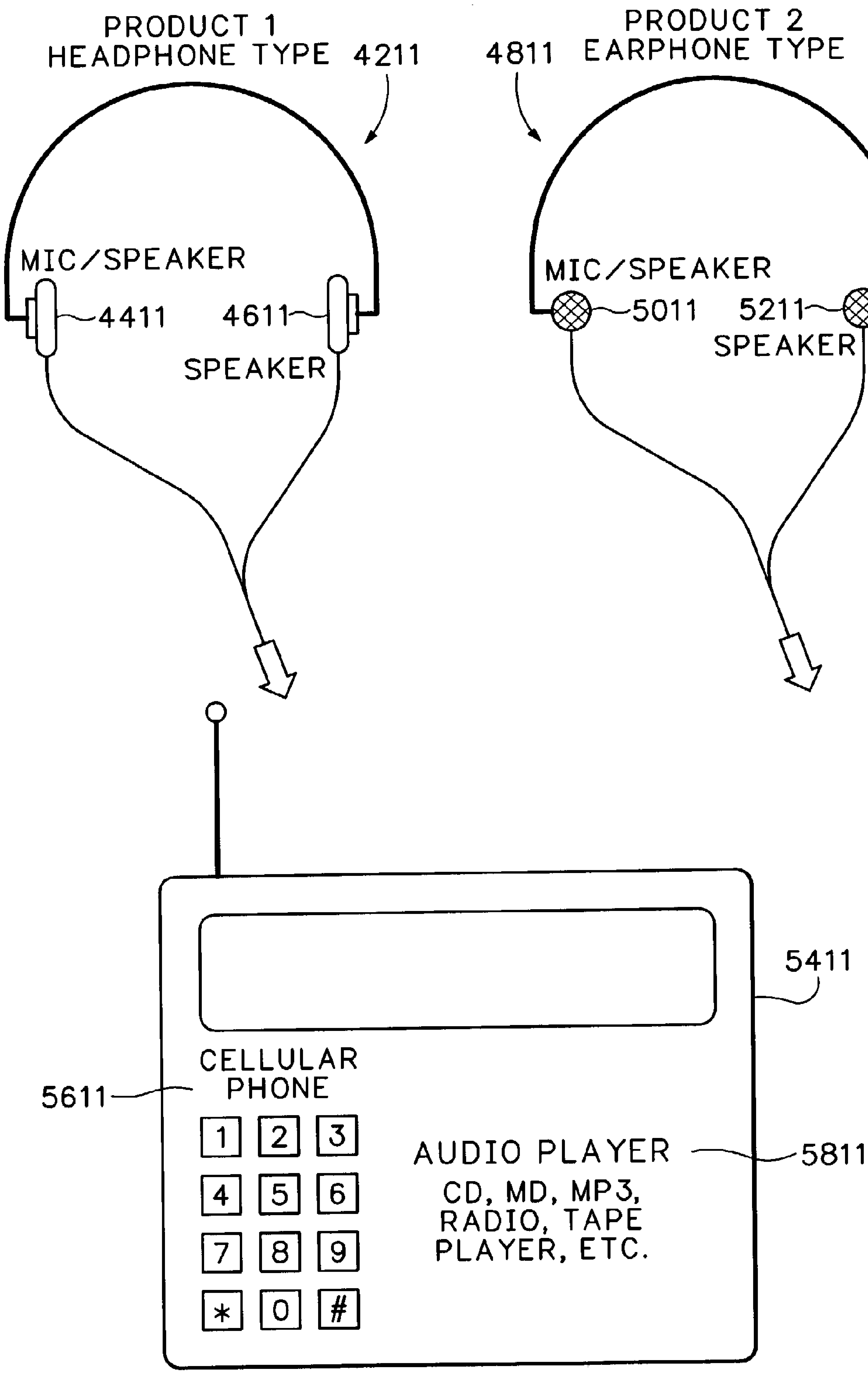

5000
1100
1200
1400
5400
5400
1900
1500
5600
5600
1000
7000
7000
5200
58
6200
6400
1000
6000
1000
6600
6800

FIG.18



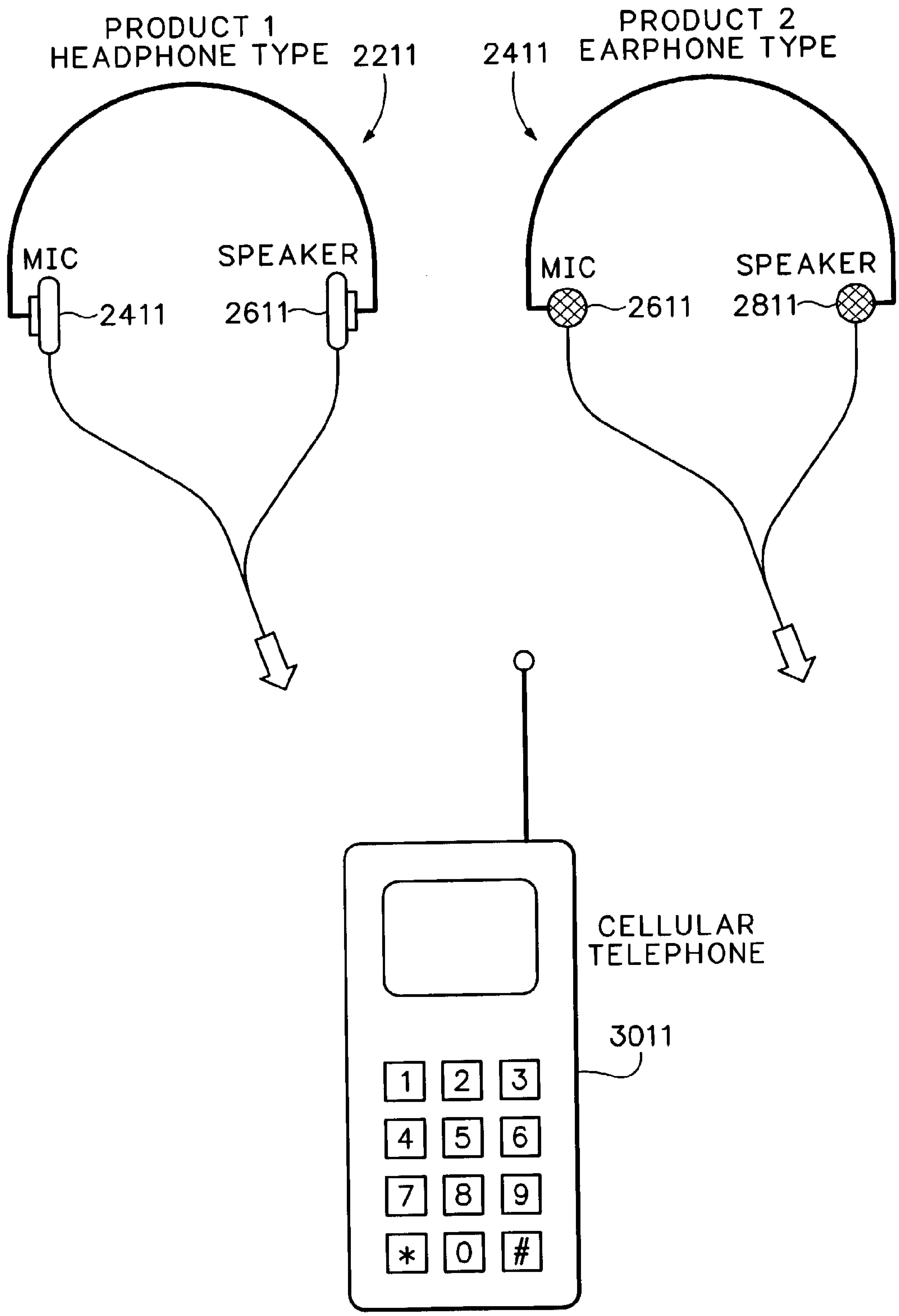
CELLULAR PHONE

FIG.19



AUDIO PLAYER WITH CELLULAR PHONE

FIG.20



CELLULAR PHONE

FIG.21

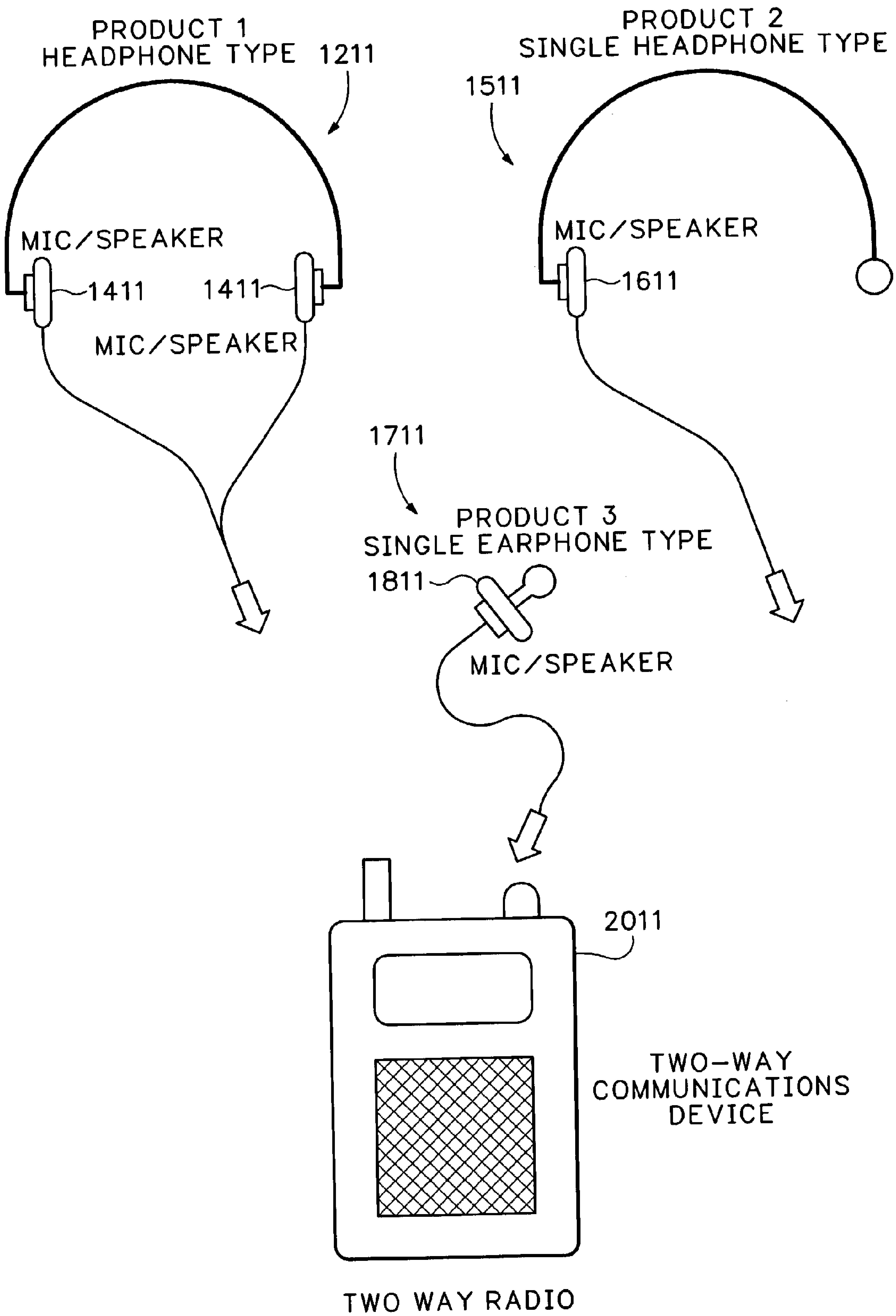
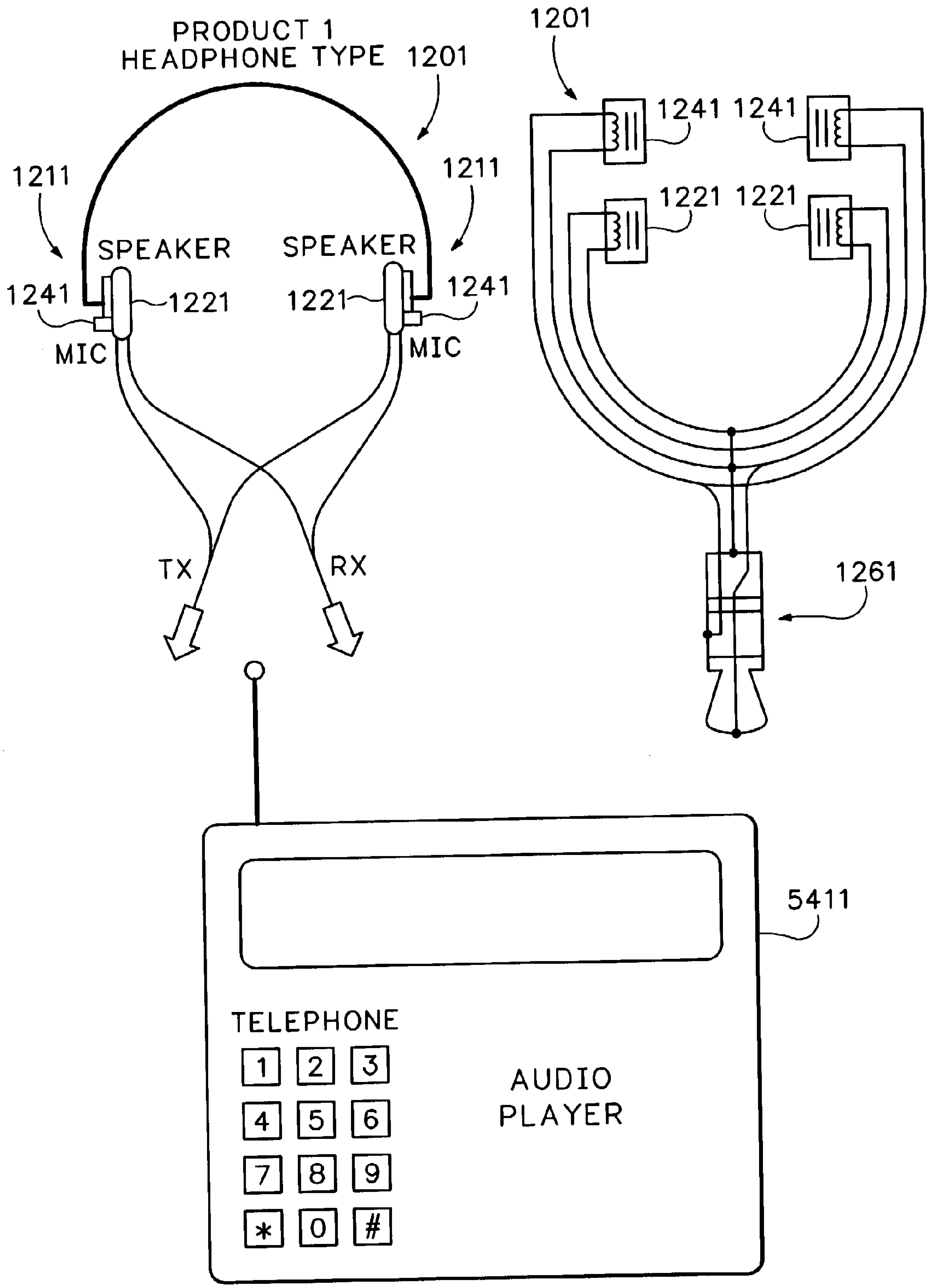

PRODUCT 1
HEADPHONE TYPE 1211
PRODUCT 2
SINGLE HEADPHONE TYPE
1511
MIC/SPEAKER
1411
1411
MIC/SPEAKER
MIC/SPEAKER
1611
1711
PRODUCT 3
SINGLE EARPHONE TYPE
1811
MIC/SPEAKER
2011
TWO-WAY
COMMUNICATIONS
DEVICE
TWO WAY RADIO

FIG.22



PLAYER WITH CELLULAR PHONE

FIG.23

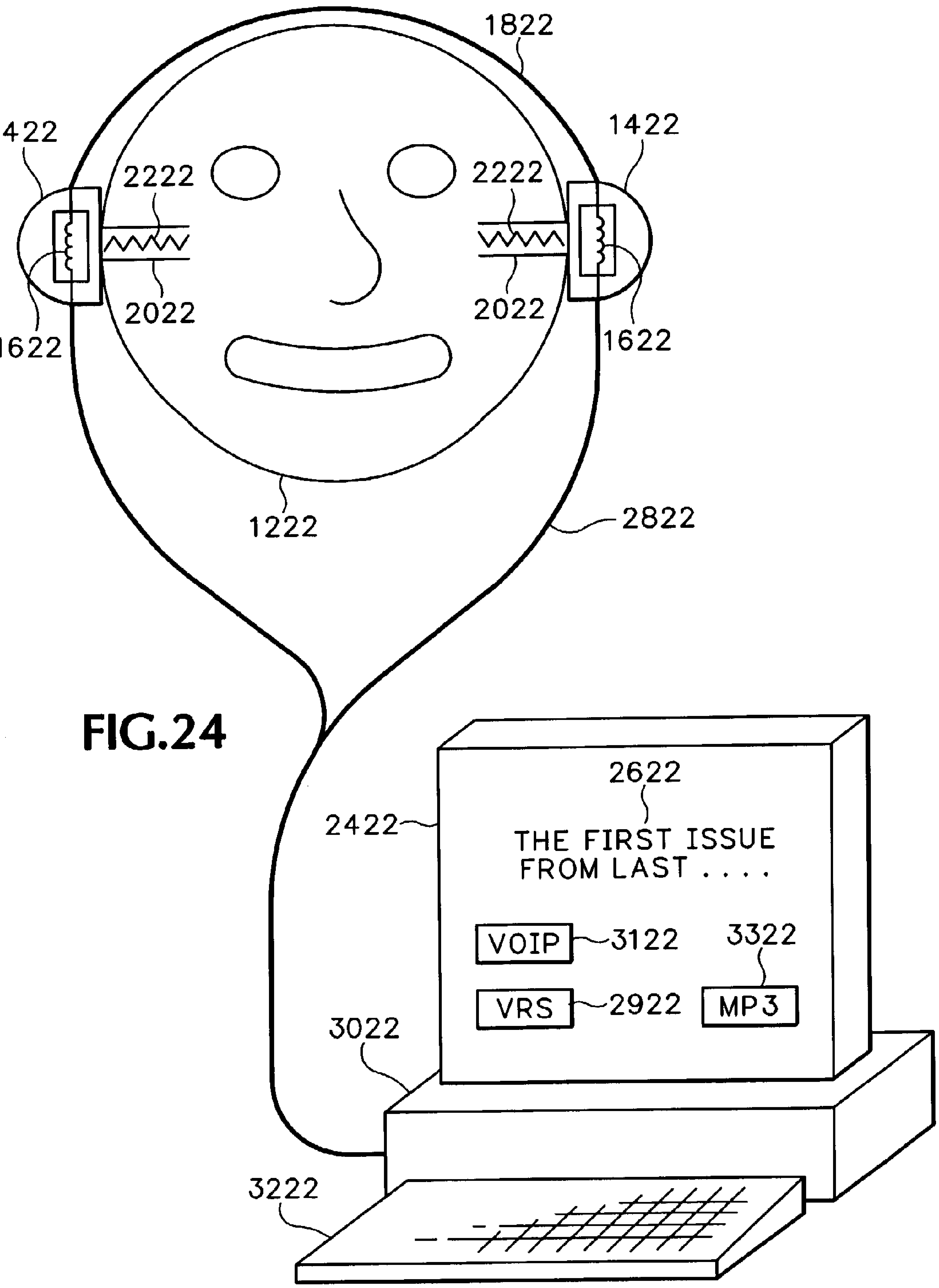

1822
1422
1422
2222
2222
2022
2022
1622
1622
1222
2822
2622
2422
THE FIRST ISSUE
FROM LAST ....
VOIP
3122
3322
VRS
2922
MP3
3022
3222

FIG.24

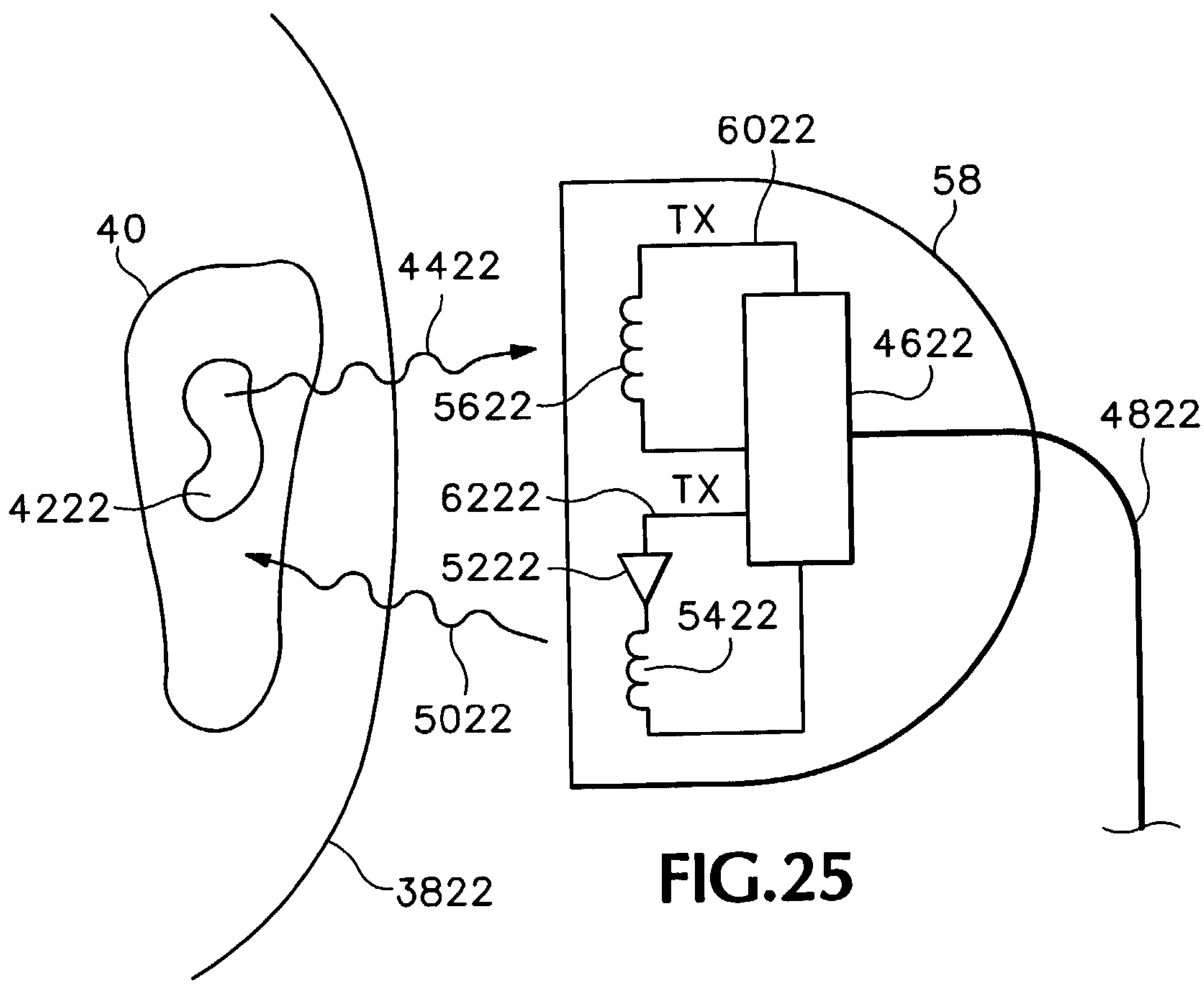

6022
58
TX
40
4422
4622
5622
4822
4222
6222
TX
5222
5422
5022
3822

FIG.25

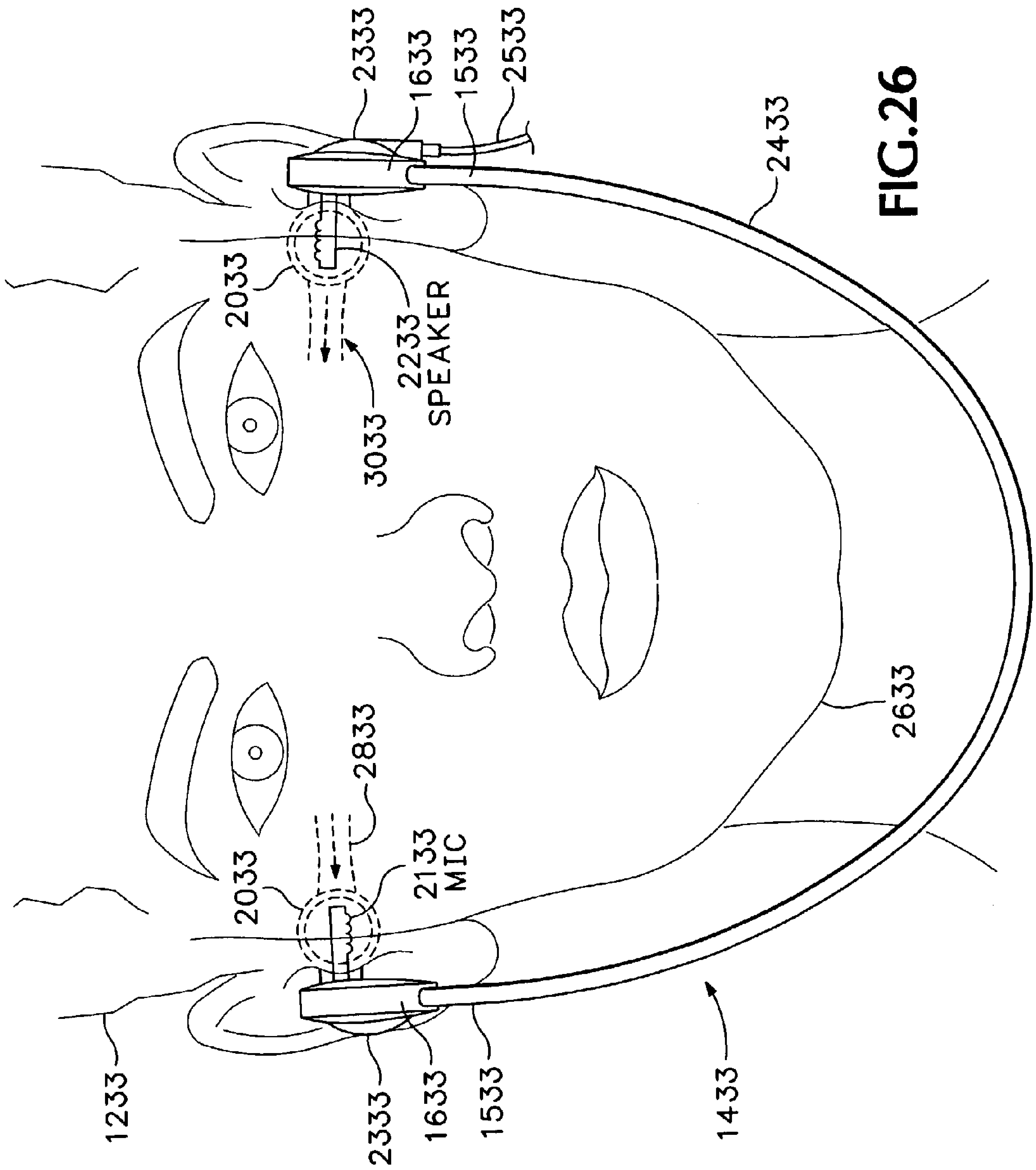

2333
1633
1533
2533
2433
2033
2233
SPEAKER
3033
2833
2133
MIC
2033
2633
1233
2333
1633
1533
1433

FIG.26

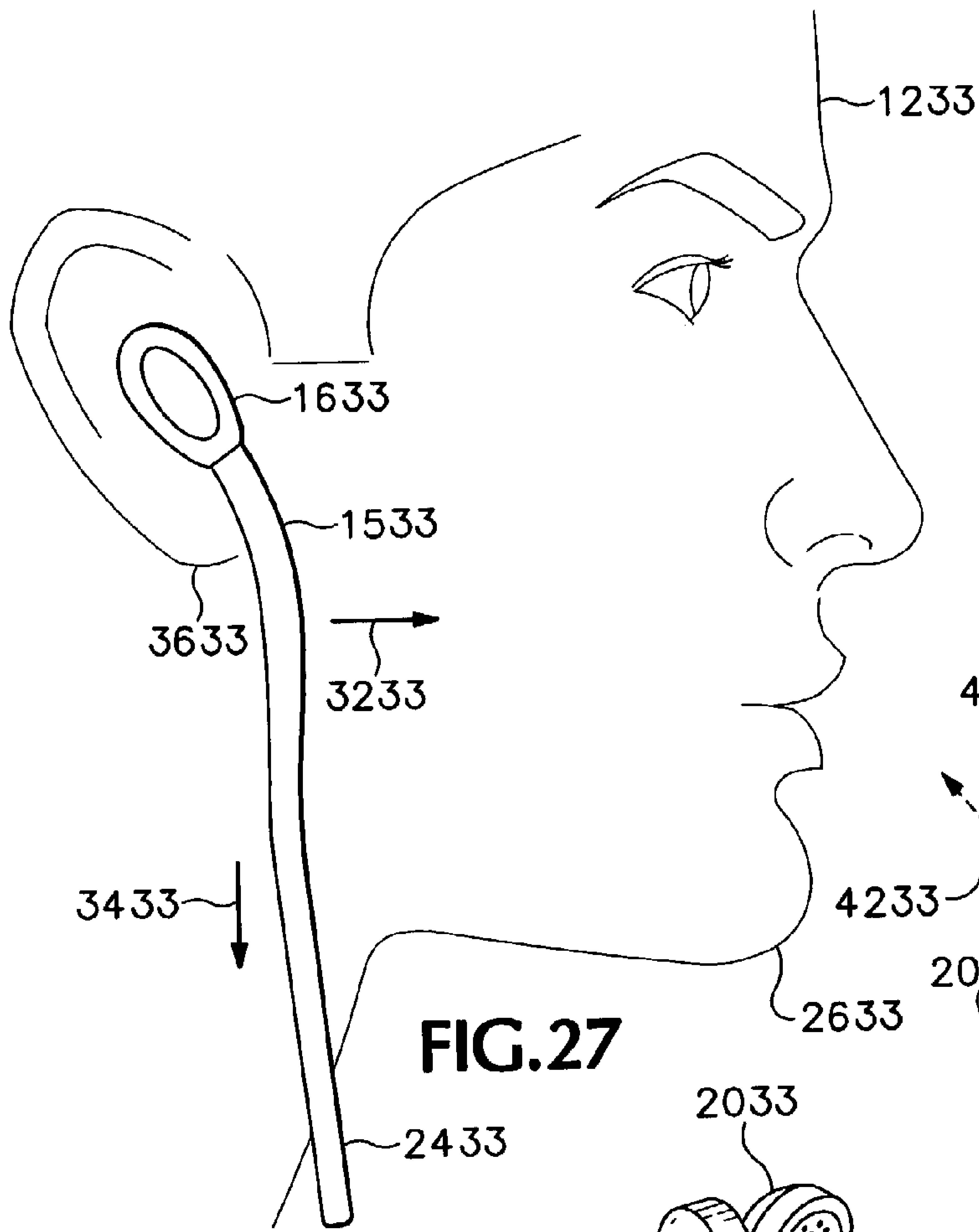

1233
1633
1533
3633
3233
3433
2433
2633
44
4033
4233

FIG.27

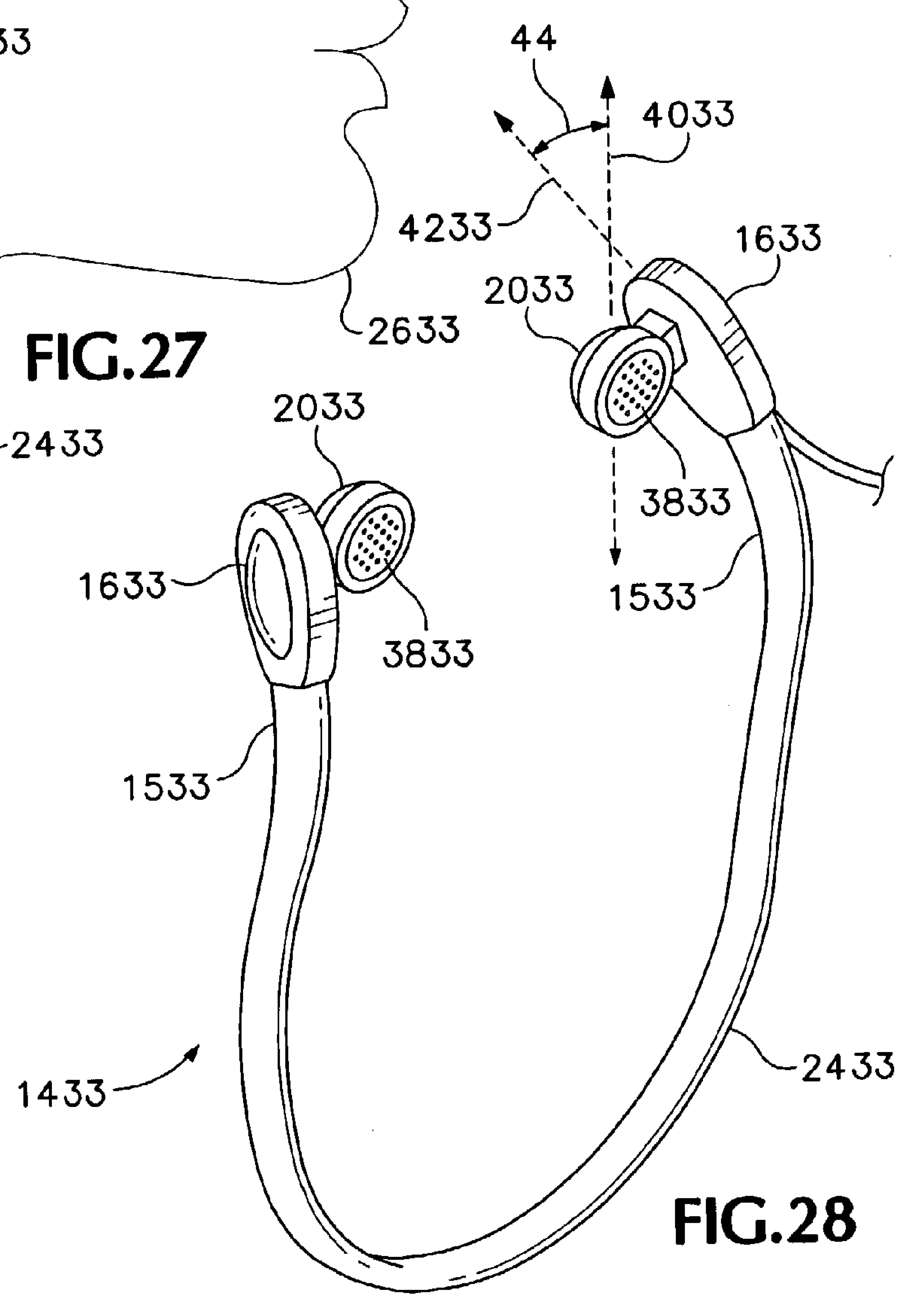

1633
2033
3833
1533
2033
1633
3833
1533
1433
2433

FIG.28

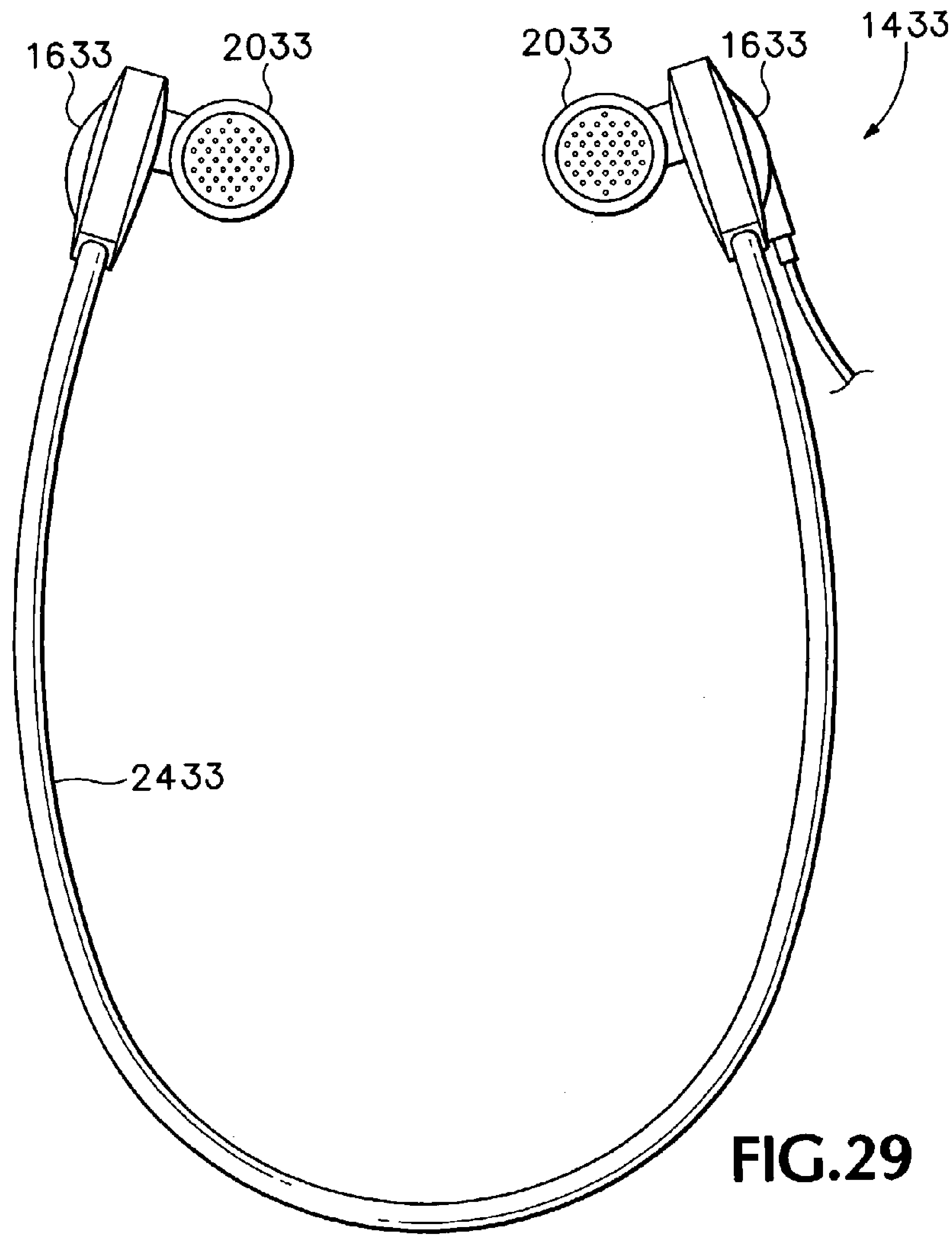

1633
2033
2033
1633
1433
2433

FIG.29

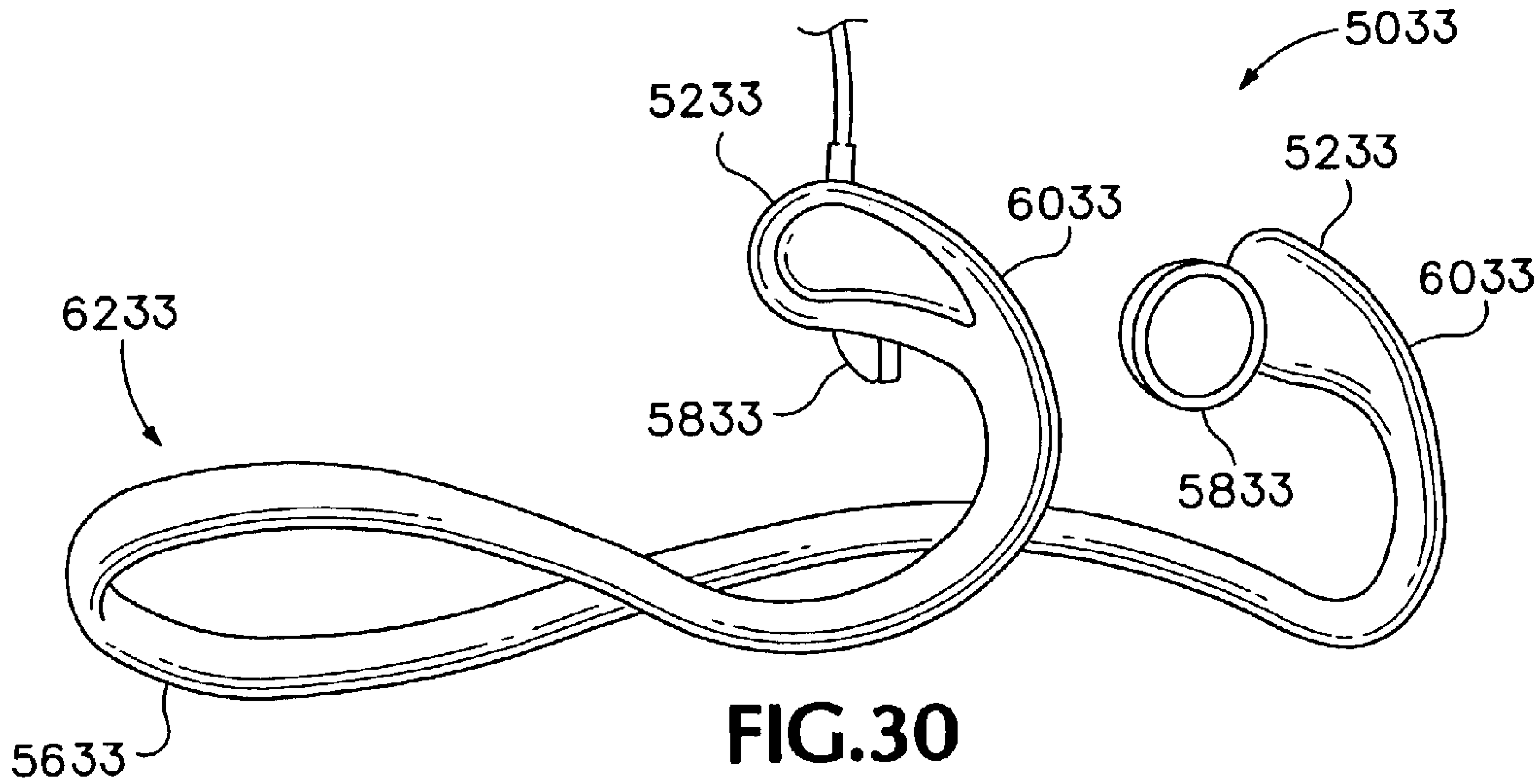

5033
5233
6033
5233
6033
6233
5833
5833
5633

FIG.30

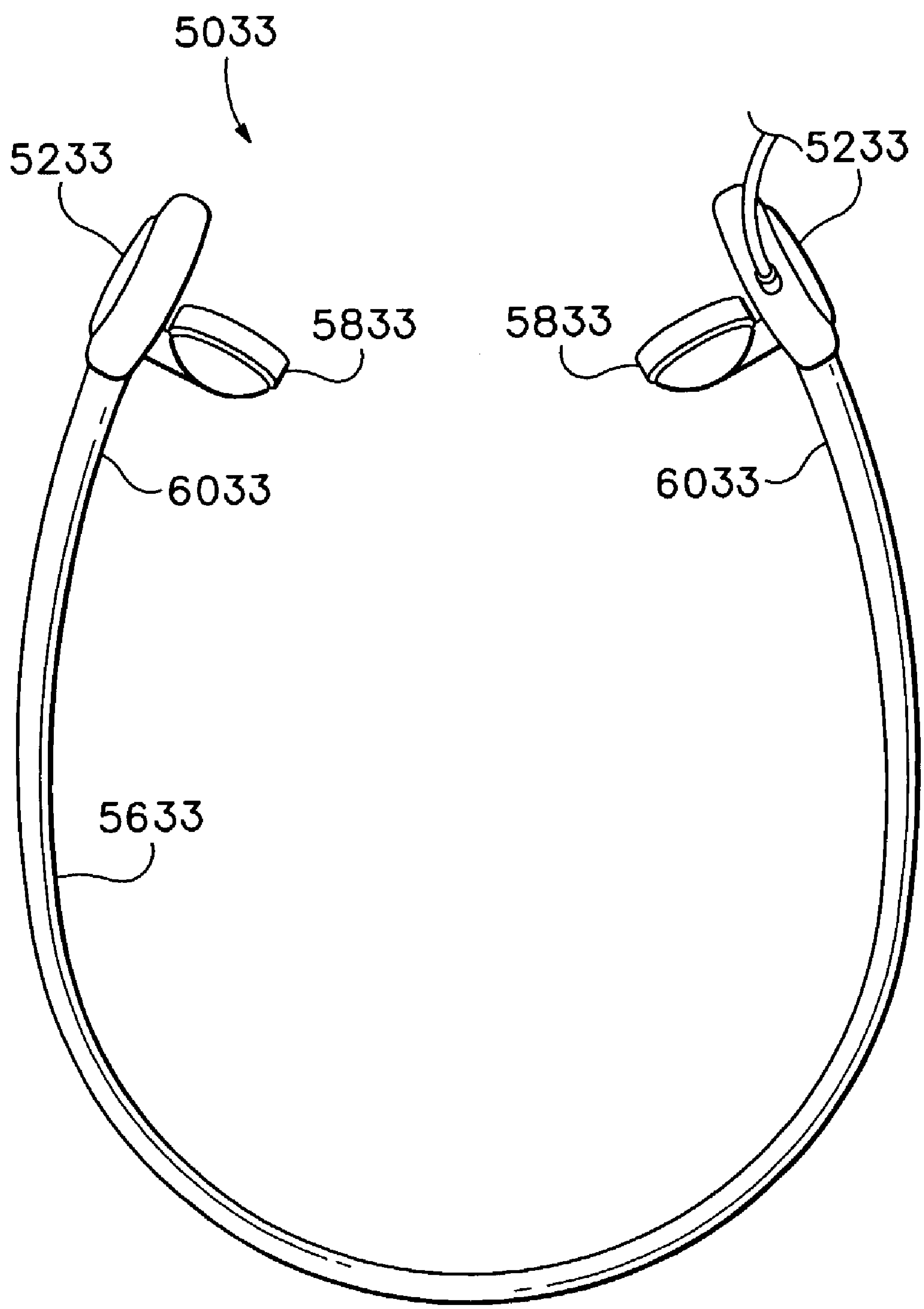


FIG.31

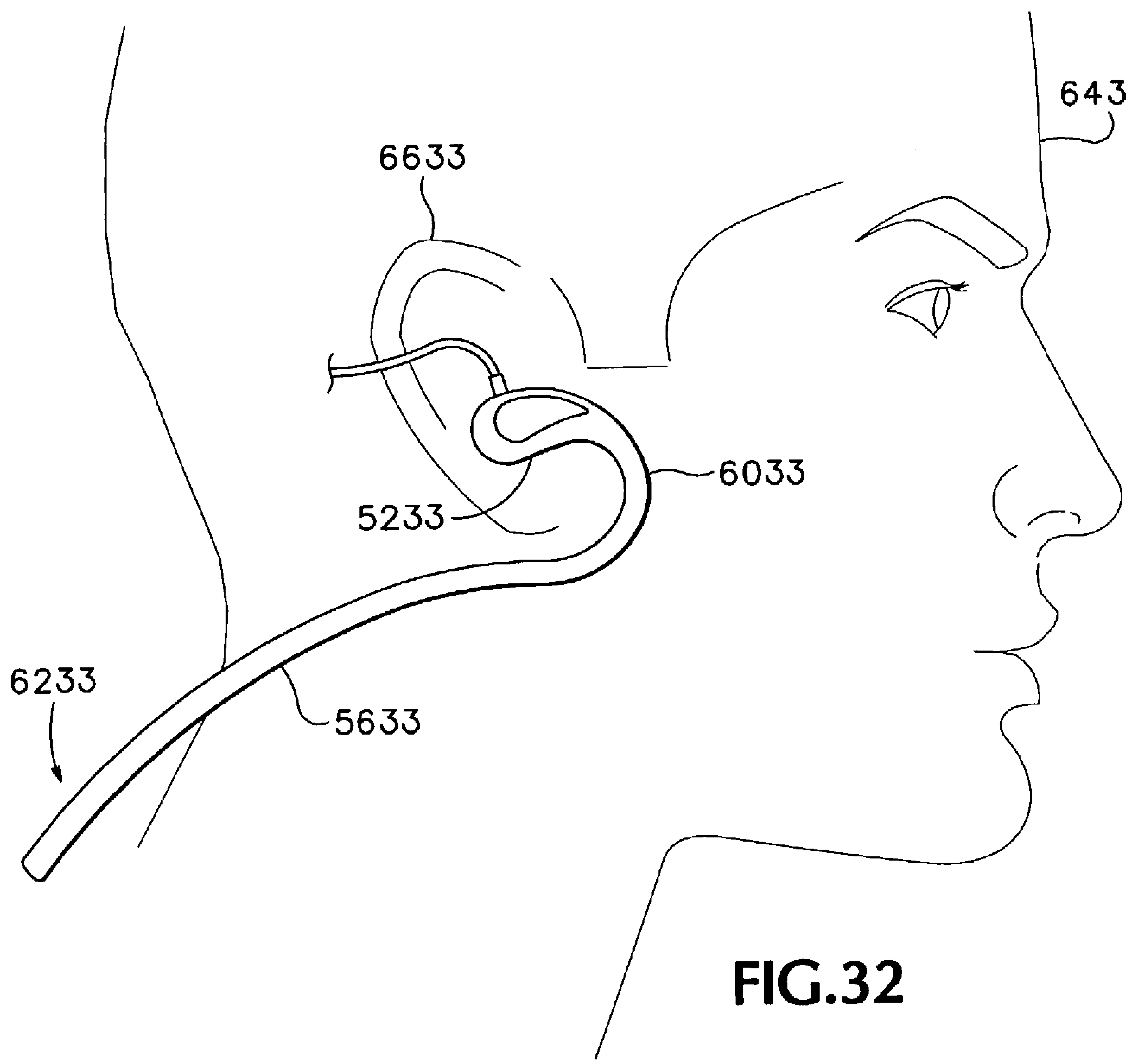


FIG.32

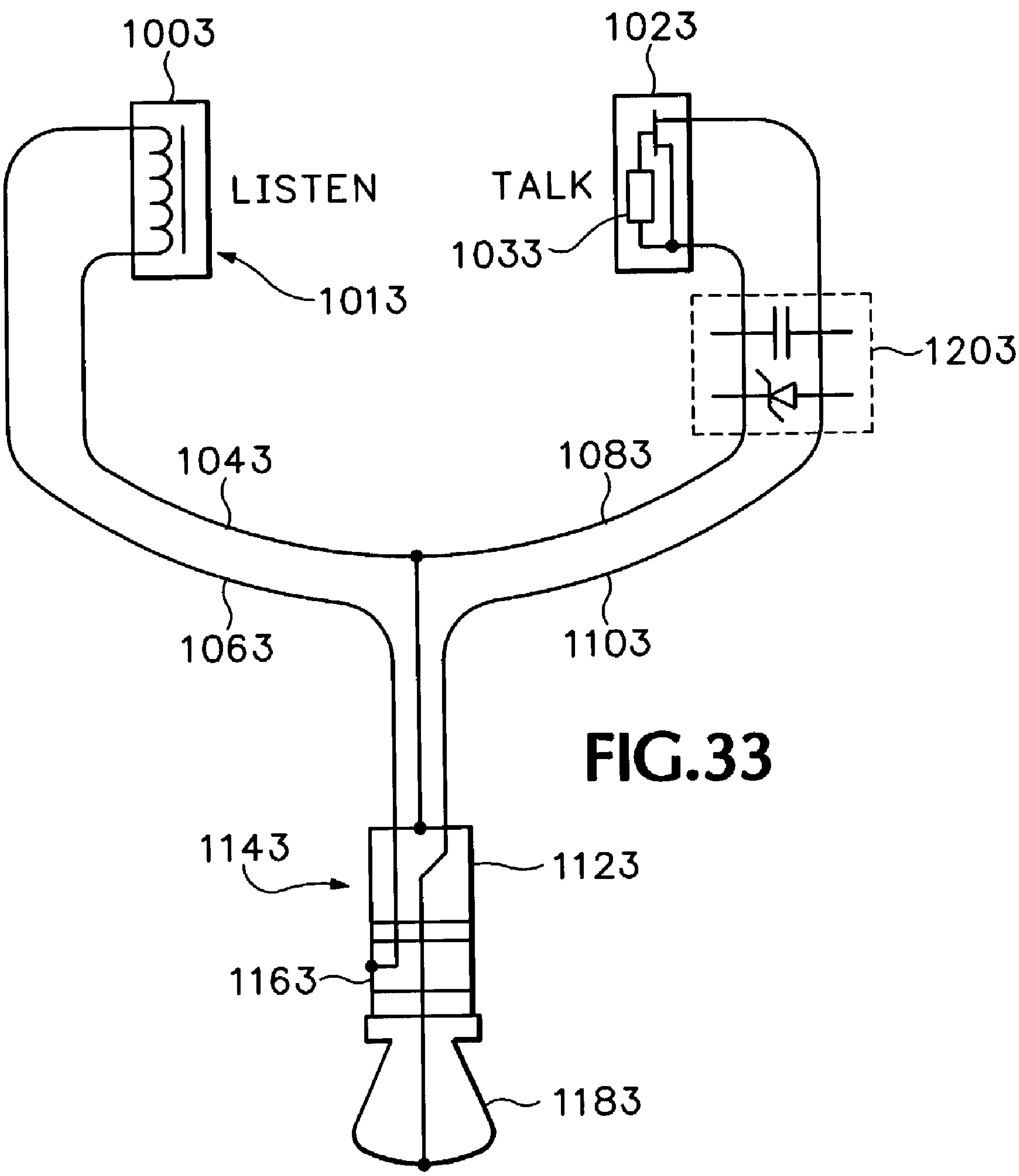

1003
1023
LISTEN
TALK
1033
1013
1203
1043
1083
1063
1103
1143
1123
1163
1183

FIG.33

AUDIO HEADSET

This application:

a) claims priority from U.S. Provisional Application Ser. No. 60/265,988, filed Feb. 2, 2001; U.S. Provisional Application Ser. No. 60/230,217, filed Sep. 5, 2000; U.S. Provisional Application Ser. No. 60/228,129, filed Aug. 25,2000; U.S. Provisional Application Ser. No. 60/223,291, filed Aug. 3, 2000, all of which are herein incorporated by reference in their entirety; and

b) is a continuation of International Application No. PCT/US01/22121, filed Jul. 13, 2001, which is:

(1) a continuation-in-part of U.S. application Ser. No. 09/878,151, filed Jun. 7, 2001, now abandoned; and

(2) a continuation-in-part of U.S. application Ser. No. 09/615,168, filed Jul. 13, 2000, now abandoned, which is a continuation-in-part of U.S. application Ser. No. 08/989,816, filed Dec. 12, 1997, now U.S. Pat. No. 6,370,245, which is a continuation-in-part of U.S. application Ser. No. 08/801,525, filed Feb. 18, 1997, now U.S. Pat. No. 5,907,538, all of which are herein incorporated by reference in their entirety.

TECHNICAL FIELD

The invention relates to a headset for simultaneously talking and listening in a full duplex mode of communication by utilizing a separate function transducer in each ear. Such devices are particularly useful in higher noise environments, such as noisy offices, inside moving automobiles and trucks, factories, heavy traffic, inside commuter trains, buses and loud music.

BACKGROUND

It is difficult to use a telephone handset in noisy environments, and particularly handsets for hand-held wireless phones. To reduce the impact of background noise, many people hold hand-held cell phones at one ear and use their index finger or the palm of their other hand to plug or cover the opposite ear. This scenario vividly portrays a necessary, yet uncomfortable method of talking and listening with portable telephones in noisy environments. With the rapid growth of portable telephones and the widespread use of these phones in noisy environments, there is a demand for new headset configurations that can significantly reduce the inconvenience of noisy interference.

A Voice Recognition System (VRS) detects and decodes human voice signals. The VRS is used in conjunction with word processing systems allowing an operator to enter words and commands orally without using a keyboard. The VRS converts the voice signals into digital words that are then either entered into a document in the word processing system or used to control word processing operations. In another application, the VRS is used in conjunction with a telephone menu system. Instead of having to press telephone keys, the user orally enters the information, command, or selection from the telephone menu.

The accuracy of the VRS in converting voice signals into the correct words and sentences varies depending on the quality of the voice signals received from the human operator. For example, most VRS systems include a microphone on a boom that is positioned over the operators mouth. The microphone picks up the operator's voice but also picks up unwanted ambient noises. These unwanted noises may include general office noise in the same room as the operator and nonverbal sounds made from the operator, such as breathing noises. These unwanted noises often cause the VRS to misinterpret the voice signals coming from the operator.

Some headsets are used for two-way communication and include a microphone boom that extends over the mouth of the user. The microphone is located on the boom in order to pick up the voice signals generated from the mouth of the user. Because the microphone also picks up ambient noise, it is difficult to use these telephone headsets in noisy environments. Two-way headsets also use metal or plastic bands to support the boom and speaker earpiece. These headsets can easily be dislodged when the user is moving and also mess up the hair or disrupt headwear on the operator. The headset is also difficult to attach and detach if the headset operator is wearing a hat. Instead of using a plastic or metal band, some headsets use wires that hang loosely down from the earpieces. However, the earpieces in these headsets can easily dislodge from the user's ears.

The present invention addresses this and other problems associated with the prior art.

SUMMARY

One embodiment of the invention provides a headset with two earpieces: one acting as a microphone, and the other acting as an earphone. Isolated from background noise and vibrations due to bone conduction, the microphone earpiece converts voice sounds from the air column in the external ear canal into electrical signals. The earphone converts electrical signals from an audio device into an audio output in the other earpiece. This headset configuration provides full duplex communication while isolating background noise.

A miniature piezoelectric, electret type, transducer is installed into one earpiece housing. This transducer is electrically dedicated to respond to a user's outgoing audio sounds. The audio sounds within the air column of the external auditory canal in one ear acoustically drive the miniature transducer producing electrical transmit (Tx) signals without the outside noisy sounds. In order to reduce and isolate bone conduction voice sounds, which result in a concentration of low frequency voice energy, a sound conduction isolation "cup" serves as a jacket that surrounds the miniature transducer inside the housing. The sound conduction cup suspends the transducer in the ear canal in a manner that improves the quality of the Tx signal generated by the transducer.

In one embodiment, a second miniature transducer is incorporated into a second identical ear-piece housing. This second transducer receives the incoming Rx electrical signal and produces acoustical sounds within the external auditory canal in the other ear of the user. The ear phone wires are joined together into one three conductor cord terminated to a standard 3.5 mm plug or 2.5 mm plug for direct plug-in. No additional electronic circuits or modifications are required. A cell phone, cordless telephone or regular corded telephone includes an external corresponding plug-in jack for receiving the headset plug.

Another embodiment of the invention addresses feedback problems and achieves improved performance relative to existing full duplex communication devices. Operating simultaneously as both an earphone and a microphone, the transducer output comprises a combined transmit and receive signal. In order to operate this circuit design with minimal feedback, a specific circuit takes this combined signal and decreases the receive signal relative to the transmit signal. The circuit also decreases the Tx feed-through from the telephone hybrid relative to the receive signal.

The full duplex headset is used in various audio applications. In one application, one headphone is used as a speaker while a second headphone is used as either a speaker or a microphone. The headphones provide stereo sound when attached to a device such as a radio, CD, MD, or MP3 player. One of the headphones switches to operating as a microphone when the device is operating as a two-way communication device, such as a cellular telephone. A user then conducts hands free two-way communications using the same headset. When the device switches back to operation as an audio player, the microphone headphone returns to operating as a speaker. The headset then returns to providing stereophonic sound. In another application, the full duplex headset is used in conjunction with a Voice Recognition System (VRS) to more accurately convert human speech into digital text.

In yet another embodiment of the invention, a headset includes earpieces for attaching to ears of an operator. A band has opposite ends that connect to the two earpieces and extends in a forward direction from the two earpieces. The band then either extends downwardly below the chin or extends backwards in back of the neck.

The foregoing and other objects, features and advantages of the invention will become more readily apparent from the following detailed description of a preferred embodiment of the invention which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a full duplex headset, showing the electrical connection of earphone and microphone earpieces to a standard plug.

FIG. **2** is a schematic diagram illustrating circuitry of the microphone earpiece shown in FIG. **1** in more detail.

FIG. **3** illustrates an example of a headset configuration in which the earphone and microphone earpieces shown in FIG. **1** may be incorporated.

FIG. **4** illustrates how an earpiece of the headset shown in FIG. **3** rests within an ear of a user.

FIG. **5** is an exploded view of a microphone earpiece for the headset shown in FIGS. **3** and **4**.

FIG. **6** is an alternative example of a headset in which the earphone and microphone earpieces shown in FIG. **1** may be incorporated.

FIG. **7** shows a cross-sectional view of an earpiece of the headset shown in FIG. **6**.

FIG. **8** shows an alternative implementation of the microphone earpiece circuitry shown in FIG. **2**.

FIG. **9** is a diagram of a full duplex digital signal processing communication circuit according to an alternative embodiment of the invention.

FIG. **10** shows the phase shift of receive audio signals output from different amplifier stages in the communication circuit shown in FIG. **9**.

FIG. **11** is a schematic diagram of a full duplex transmit and receive circuit according to another embodiment of the invention.

FIGS. **12**, **13** and **14** are alternative embodiments of the full duplex circuitry.

FIG. **15** shows a cross-sectional view of an earpiece that contains the full duplex circuitry.

FIG. **16** shows a perspective view of the earpiece shown in FIG. **15**.

FIG. **17** shows how the earpiece in FIGS. **15** and **16** rests within an ear of an operator.

FIG. **18** is a diagram showing the full duplex circuitry used with various two-way communications devices.

FIG. **19** is a diagram of a retractable earphone and a wireless earphone that operate as both a speaker and a microphone.

FIG. **20** is a diagram of a headset that has two headphones or earphones that operate as speakers when connected to an audio device and one of the headphones or earphones switches to operating as a microphone when the device operates as a two-way communication device.

FIG. **21** is diagram of a headset where one headphone or earphone operates as a microphone and the other headphone or earphone operates as a speaker.

FIG. **22** is a diagram of the headset where each headphone or earphone operates as both a microphone and speaker.

FIG. **23** is a diagram of a headset that has speakers inside the headphones and microphones attached to the outside of the headphones.

FIG. **24** is a diagram of a headset that detects sound waves from an ear canal and sends electrical signals generated from the sound waves directly to a Voice Recognition System.

FIG. **25** is a headphone that feeds transmit signals back to the headphone operator.

FIG. **26** is a front view of a loop down headset.

FIG. **27** is a side view of the loop down headset shown in FIG. **26**.

FIG. **28** is a perspective view of the loop down headset.

FIG. **29** is a front view of the loop down headset.

FIG. **30** is a perspective view of a loop back headset.

FIG. **31** is a top view of the loop back headset.

FIG. **32** is a side view of the loop back headset.

FIG. **33** is a schematic diagram of one full duplex circuit that can be used in either the loop down headset or the loopback headset.

DETAILED DESCRIPTION

FIG. **1** is a schematic diagram of a full duplex headset. The headset has two earpieces: an earphone earpiece **100** and a microphone earpiece **102**. Each earpiece has two electrical terminals, with one serving as the common or "ground" node. A pair of wires **104**, **106** and **108**, **110** are connected to these terminals, and are ultimately joined in a single cord terminating in a connector plug **114**. The wires connected to the ground node **104**, **108** are joined together and terminate at the sleeve **112** of plug **114**. The wire connected to the opposite terminal of the earphone relative to the common terminal is connected to the ring portion **116** of the plug **114**. On the other side of the headset, the wire **110** in the microphone **102** is connected to the tip portion **118** of the plug **114**.

The earphone **100** contains a transducer **120** that converts an electrical signal into an audio output. The microphone earpiece **102** contains a transducer that converts an audio input into an electrical signal, which is communicated to a telephony device via the wires **108**, **110**.

By placing the microphone in the operator's ear, the transducer in the microphone can detect voice signals that pass from the users vocal cords through the operators head and out the external ear canal. Since the microphone is located inside the ear canal, ambient noise is filtered from the transducer.

FIG. **2** is a schematic diagram illustrating circuitry within the microphone earpiece in more detail. The circuitry within the earpiece in this particular implementation includes a piezoelectric transducer **200** coupled across the gate node **202** and drain node **208** of a field effect transistor **206**. The drain node **208** of the field effect transistor **206** is connected to the wire **110** that extends from the earpiece **102**. The source node of the field effect transistor is connected to the wire for common ground node (**108**).

When the wearer of the headset speaks, the resulting voice sounds in the air column within the external auditory canal drive the piezoelectric transducer **200**. The field effect transistor **206** transfers the electrical signal induced by the voice sounds through the wire **110** and into interface circuitry within the telephony device. This interface circuitry is conventional, and may include a resistor **210** coupled between the input port **212** that receives signals from the wire **110**, on one side, and the VCC power supply on the other side. The telephony device may also have an amplifier **214** and other conventional interface circuitry to process the incoming electrical signal. The common ground wire **108** is connected to one terminal of the piezoelectric transducer **200**. The drain of the field effect transistor **206** is coupled to ground via another port **216** of the telephony device.

The headset configuration shown in FIG. **1** can be incorporated into a variety of headsets. FIG. **3** illustrates one possible example of a headset configuration in which the circuitry shown in FIGS. **1** and **2** may be incorporated. The headset shown in FIG. **3** is similar to the headsets typically used with portable radios, tape players, and CD players. Each of the earpieces **304**, **306** have a similar structure. In particular, each earpiece includes a circular disk portion **300**, **302** with a flat face. When resting inside the ear, the face of the earpiece is designed to be oriented in the direction of the external ear canal. A grill **308**, **310** on the face of the earpiece allows voice sounds to be communicated to the microphone and from the earphone transducers.

A neck portion **312**, **314** of the earpiece housing extends from the disk portion **300**, **302** and is connected to the headset frame piece **316**, **318**. A metallic headband **320** fits within a sleeve of the frame pieces **316**, **318** and allows the user to adjust the size of the headset.

FIG. **4** shows an expanded view of the earpiece **306** from the headset shown in FIG. **3**, resting within a user's ear **400**. This particular illustration shows how the left earpiece **306** rests within a pocket of the ear such that the face **302** of the earpiece is oriented in the direction of the external ear canal **402**. The neck portion **318** of the earpiece extends out of the ear and acts as a conduit for the cord carrying the two wires from the transducer inside the earpiece.

FIG. **5** is an exploded view of a microphone earpiece designed for the headset shown in FIGS. **3** and **4**. As shown in FIG. **5**, the earpiece housing includes a plastic disk-shaped housing **500** formed into a unitary piece along with the neck portion **502** of the housing **500**. A cover **504** fits into an opening **501** in the housing **500** and has a grill portion **506** that allows audio sounds from the external auditory canal to pass into the housing **500** and drive a miniature microphone **508**.

The microphone **508** is implemented with a piezoelectric transducer, and in particular, an electret-type transducer. The microphone sits within a cup **510** that acts as an acoustical isolator. The cup **510** fits tightly around the sides and rear of the electret and fills in the space between the electret and the inner walls of the earpiece housing **500**.

The cup **510** acts as an acoustical isolator to prevent sounds attributable to bone conduction from reaching the microphone **508**. Preferably, the acoustical isolator is made of a material that has a high air content isolate vibrations attributable to bone conduction. A variety of materials may serve this function, including, but not limited to, Styrofoam, plastic, wood, perlite, etc.

FIG. **6** illustrates another example of a headset configuration that can incorporate the circuitry shown in FIG. **1**. This particular configuration is especially effective in high noise environments because each of the earpieces **600**, **602** has a nipple **604**, **606** that penetrates into and fits snuggly within the wearer's external ear canal **402** (FIG. **4**). The nipple **604**, **606** comprises an umbrella-like shroud **608**, **610** made of a soft, flexible material that conforms to the shape of the external auditory canal. The pinnacle of the shroud **608**, **610** has an opening **612**, **614** that allows air to pass to the transducer within the housing. The stalk **616**, **618** of nipples **604**, **606** is made of a harder plastic and is roughly cone-shaped, with a circumference that decreases toward the openings **612**, **614** of the nipples.

FIG. **7** shows a cross-sectional view of the nipple earpiece shown in FIG. **6**. The stalk **618** of the nipple snaps onto an earpiece housing **700** that houses a piezoelectric microphone **702**.

To reduce ear fatigue, the wires stemming from each earpiece extend through the housing and into the frame body **620**, **622** of the headset (FIG. **6**). This upward orientation of the wiring through the frame of the headset reduces the stress that would otherwise be directed to the earpiece if it extended from the bottom of the earpiece. While this particular configuration may tend to reduce fatigue on the ear, it is also possible to configure the earpieces so that the wiring extends from the side or bottom of the earpiece housing.

It is important to note that the headset configurations shown in FIGS. **4**–**7** represent only some examples of the many possible configurations in which the full duplex circuit configuration shown in FIG. **1** may be incorporated. While these configurations include a headset frame that fits over the wearer's head, it is also possible to implement the full duplex headset in a pair of earpieces that are held to the user's head in some other fashion. One possible alternative is to have ear clips mounted on each of the earpiece housings that clip around the wearer's ears. Another alternative is to use earpieces such as the ones shown in FIG. **6** that fit snuggly within the auditory canal without the need for external support from a headset frame.

The headsets described above provide hands-free full duplex communications without having to use an annoying microphone extension arm. A microphone does not have to be positioned near the mouth since the voice sounds are essentially provided through the ear canal.

Multiple transducer housing styles can be used to suit the various preferred choices of use. An earpiece attachment that protrudes outside the ear canal can be used for less noisy environments. The lightweight ear microphones use small miniature electro-dynamics transducers weighing approximately 5 grams or 0.18 oz. to minimize fatigue. The lightweight piezoelectric transducers further improve performance and reduce weight. Lightweight head bands, ear supports, and contoured transducer housings, such as those designed for security personnel, and the hearing impaired, provide snug fit in the outer car canal.

FIG. **8** shows a variation on the microphone earpiece circuit shown in FIG. **2**. A filter circuit **698** includes a capacitor **710** and an inductor **712**. The filter circuit **698** is coupled between the source and drain terminals of FET transistor **206**. The capacitor **710** provides DC blocking between node **208** and node **216**. The inductor **712** provides a low impedance at low audio frequencies and a high impedance at high audio frequencies. In one example, the inductor **712** is selected so that there is approximately ten times the impedance across FET transistor **206** at 3000 Hertz than at 300 Hertz.

The filter circuit **698** attenuates the low frequencies associated with bone conduction and low audio frequencies. Thus, the circuit **698** filters out some of the unwanted bone conduction and low frequency voice components that may be picked up by the transducer **200** while residing in the ear canal. Since consonants are generally pronounced using higher frequency components, the circuit **698** also provides better sound detection for consonants. In one embodiment, the inductor is made from a circular core material and wire is wrapped around this circular core material.

A transmit circuit **713** is used in cellular phones, cordless telephones or phone handsets. The transmit circuit **713** includes a resistor **210** and a capacitor **714**. A connection **718** is coupled to the tip **118** of the plug **114** (FIG. **1**). The voltage of the transmit signal at connection **718** is increased before being amplified by amplifier **214**.

Full Duplex Earphone—Using One Transducer

FIG. **9** shows a circuit **8** that uses a single transducer **10** for full duplex analog earphone and microphone operation. A combination earphone and microphone transducer **10** is coupled between an inverting input and an output of an operational amplifier (op amp) **12**. An earpiece **46** contains the transducer **10** and is adapted for inserting into the ear canal of a human operator. A noninverting input of op amp **12** is coupled to the noninverting input of an op amp **14**. An inverting input of op amp **14** is coupled to a balancing resistor **40** and through a resistor **42** to an output of op amp **14**. The balance resistor **40** is used to control the gain of the Rx signal output from op amp **14**.

The output of op amp **12** is coupled through an analog to digital (A/D) converter **16** to a signal adder **20**. The output of op amp **14** is coupled through an A/D converter **18** and a receive adaptive phase canceller **19** to the signal adder **20**. An output **21** of signal adder **20** is fed through a digital to analog (D/A) converter **22** into the Tx input of a hybrid network **24**. The Rx output of the signal adder is also fed through a transmit adaptive phase canceller **28** into signal adder **30**. The output of the hybrid network circuit **24** is fed through an A/D converter **26** into the signal adder **30**. An output of signal adder **30** is fed through a D/A **32** into the noninverting inputs of op amps **12** and **14** at node **44**. Node **44** is also coupled by resistor **38** to ground.

In one embodiment, the components within the dashed line **48** describe functions that are implemented in software by a Digital Signal Processor (DSP). Some or all of the components within the dashed line can alternatively be implemented by discrete digital components. For example, the A/D and D/A converters may be implemented as discrete components while the signal adders and adaptive phase cancellers may also be implemented as discrete components or in software in a DSP.

The transducer **10** is used as both a microphone for detecting and generating audio signals from the operators voice and as an ear phone that generates audio signals heard by the operator from Rx audio signals received over the telephone line **25**.

The audio signals from the talking operator are converted by the transducer **10** into Transmit (Tx) signals. The transducer **10**, when operating as an earphone, converts receive signals (Rx) from the telephone line **25** into audible signals. These audible signals are heard in the external ear canal of the operator through the earpiece **46**.

The hybrid network **24** represents circuitry used to compensate for the reactive characteristics of the telephone network connected to telephone line **25**. The hybrid network **24** is a 2 to 4 wire hybrid circuit. The telephone line **25** is a two wire line that connects to 4 wires of the communication circuit **8**. In the case of a wireless communication network, such as a cellular telephone, the hybrid network **24** may represent the voice encoder and transceiver circuitry in the cell phone or in the cell phone base station. Network **24** represents any circuitry in a landline based telephone network, or cellular telephone network that may leak part of the transmit signal back to the receive path of the communication circuit.

A receive audio signal Rx from telephone line **25** goes through the hybrid network **24**, A/D **26** and D/A **32** into the noninverting inputs of op amps **12** and **14**. A current mirror characteristic of the op amps **12** and **14** cause the same Rx signal to be output at the inverting inputs of op amps **12** and **14**. The Rx signal is generated across the transducer **10**. The transducer **10** converts the Rx signal into an audio signal that is output in the ear canal of the operator. The Rx signal is also output from the outputs of op amps **12** and **14**.

The transducer **10** provides an inductance and operates in conjunction with the resistance of resistor **36** to filter out low frequencies in the Rx signal that are generated across transducer **10**. Because the transducer **10** generates a higher impedance at higher frequencies, more gain is provided by op amp **12** for the higher frequency components and less gain is generated for low frequency components of the Rx signal.

When the operator talks, the audio signals output through the ear canal of the operator are converted into an electrical Tx signal by transducer **10**. The Tx and Rx signals **52** are output from op amp **12**.

The op amp **14** is basically a resistive circuit that does not effect the phase of the output Rx signal **50**. However, the op amp circuit **12** has a reactive inductive component created by transducer **10**. The phase of the Rx signal **52** output from op amp **12** is therefore shifted from the phase of Rx signal **50** output from op amp **14**. The Rx signal **50** output from op amp **14** and the Rx signal **52** output from op amp **12** are shown in FIG. **10**.

The Tx and Rx signals **52** output from op amp **12** are converted into digital data by A/D **16**. The Rx signal **50** output by op amp **14** is converted into digital data by A/D **18**. An Rx adaptive phase canceller **19** aligns the phase of Rx signal **50** 180 degrees out of phase with respect to the phase of Rx signal **52**. The signal adder **20** then adds the 180 degree out of phase Rx signal from phase canceller **19** with the Tx+Rx signal **52** output from A/D **16**. The output **21** of signal adder **21** has a substantially reduced Rx signal and primarily consists of the Tx signal. Alternatively, the phase canceller **19** could align the phase of Rx signal **50** with the phase of Rx signal **52**. The signal adder **20** then could simply subtract the Tx+Rx signal output by A/D **16** from the Rx signal output from phase canceller **19** to substantially cancel out the Rx signal output by signal adder **20**. The desired target reduction of the Rx signal output from the signal adder **20** is 30 decibels (dbs) below the Tx signal.

The Tx signal in converted back into an analog signal by D/A **22** then fed into the hybrid network **24** of the telephone system. The Tx signal is then output on the telephone line **25** or to the voice codec or other telephone circuitry that encodes the Tx signal for transmission over a landline or wireless voice channel of the telephone network.

Another objective of the communication circuit **8** is to compensate for the Tx signal that may leak through the hybrid network **24** back over the receive channel. When the telephone line **25** is converted from the 2 wires of the telephone line **25** to the 4 wires of the communication circuit **8**, there are reactive effects in the hybrid network transformers that allow some of the Tx signal at input **21** to lead through the hybrid network **24** back to the input **23** of circuit **8**.

The Rx signal plus the Tx signal leakage at input **23** are both fed into the A/D converter **26**. The Tx signal from the output **21** of signal adder **20** is fed into the Tx adaptive phase canceller **28**. The phase canceller **28** operates in the same manner as the phase canceller **19** only for the Tx signal instead of the Rx signal. In other words, the phase canceller **28** shifts the Tx signal at output **21** to 180 degrees out of phase with respect to the Tx signal at the input **23**.

The signal adder **30** then adds the Rx+Tx (leakage) signal with the 180 degree phase shifted Tx signal output from adaptive phase canceller **28**. The signal adder **30** subtracts the Tx signals and outputs primarily only the Rx signal. Any remaining Tx signal output from the signal adder **30** is about 30 dbs below the Rx signal.

In summary, the desired Tx signal at the output **21** of circuit **8** is 30 dbs higher than any Rx signal. Further, the Rx signal on line **34** is 30 dbs higher than any Tx signal on line **34**.

Opposite Polarity Transducers

Referring to FIG. **11**, a transmit and receive circuit **1000** is coupled at a first end to a headset **1100**. The headset **1100** includes headphones **1400** and **1200** that contain transducers **1500** and **1900**, respectively. A strap **1700** holds the two headphones **1400** and **1200** together. The transducer **1500** is coupled between ground and the circuit **1000** in an opposite polarity than transducer **1900**.

On the opposite end of the transmit and receive circuit **1000** is a voice operated transmission (VOX) circuit **4000**. The VOX circuit **4000** detects a transmission signal (Tx) generated by the operator of headset **1100**. When a sufficient Tx signal is detected, the VOX circuit **4000** activates a Radio Frequency (RF) transmit and receive device **4200** to transmit the Tx signal over antenna **4400** to a receiving device. When the Tx signal is not detected, the VOX circuit **4000** enables the transmit and receive device **4200** to receive any incoming receive signals (Rx).

In one example, the transmit and receive device **4200** is a two-way radio or walkie-talkie. However, it should be understood that the transmit and receive circuit **1000** operates with any two-way communication device **4200**, including but not limited to cellular telephones, wireless phones, landline telephones, transceivers or walkie-talkies, etc. In the case of a telephone, the VOX circuit **4000** may not be needed.

The receive signal (Rx) on input **1800** from VOX **4000** is coupled to an automatic level control circuit **2000**. The automatic level control circuit **2000** includes an op-amp **2200** coupled at an output to the base of a PNP transistor **2400**. The output of transistor **2400** is coupled to the gate of a Field Effect Transistor (FET) **2600**.

A voltage level is selected at input node **2800** of level control circuit **2000**. If the Rx signal at node **2800** rises above a predetermined voltage threshold, the signal output from op-amp **2200** activates transistor **2400**. That, in turn, increases the signal at the gate of FET **2600**. The increased gate signal reduces the impedance between the source and drain terminals of FET **2600**. The reduced impedance across FET **2600** pulls down the Rx signal at node **2800**. Thus, the automatic level control circuit **2000** decreases the impedance across FET **2600** when the Rx signal at node **2800** increases above the threshold voltage. The Rx signal output from op-amp **2200** is in turn maintained at a constant level.

The Rx signal is output from automatic level control circuit **2000** to op-amps **3200** and **3400**. The output of op-amp **3200** is coupled to the positive terminal of transducer **1500** in headphone **1400**. The output of op-amp **3400** is coupled to the negative terminal of transducer **1900** in headphone **1200**. The positive terminal of transducer **1900** is coupled to ground and the negative terminal of transducer **1400** is coupled to ground.

The Rx signal is fed into the op-amps **3200** and **3400** and back out to the transducers **1500** and **1900**. Because the transducers **1500** and **1900** have reversed polarities, a listener will hear a negative Rx signal in one ear and a positive Rx signal in the other ear. In other words, the Rx signals output from the two headphones **1400** and **1200** are 180 degrees out of phase. However, it has been discovered that the human brain does not distinguish between the positive and negative Rx signals output by transducers **1500** and **1900**. Thus, any incoming receive Rx signal output from headphones **1400** and **1200** sounds exactly the same in both ears of the headphone user. The Rx portion of the signal output from op-amps **3200** and **3400** are in phase. The two Rx signals fed into the negative and positive terminals of differential amplifier **3800** therefore cancel out.

When the user of headset **1100** talks, a Tx signal is output from transducer **1500** and the same Tx signal is output by transducer **1900**. Because the transducers **1500** and **1900** are in reversed polarity, the two Tx signals output through op-amps **3200** and **3400** are out of phase. Therefore, the two Tx signals at the negative and positive terminals of differential amplifier **3800** are added together generating double the Tx signal (2Tx) at the output of op-amp **3800**.

FIG. **12** is an alternative embodiment of the full duplex circuit **1000** previously shown in FIG. **11**. Instead of using an automatic level circuit **2000**, a manual Rx level circuit **4500** is used to adjust the Rx voltage level into op-amps **3200** and **3400**.

Because the Rx signal output from the two op-amps **3200** and **3400** are the same phase, the Rx signal will be cancelled by differential amplifier **3800**. As described above, the Tx signals output from op-amps **3200** and **3400** are of opposite polarity coming out of op-amps **3200** and **3400**. Therefore, the Tx signals into differential amplifier **3800** are added together generating a double the Tx signal.

FIG. **13** shows another embodiment of the microphone and speaker circuit. A transmit and receive circuit **6011** is coupled at a first end to a headset **1211**. The headset **1211** includes headphones **1411**A and **1411**B that contain transducers **6211** and **6411**, respectively. A strap **6611** holds the two headphones **1411**A and **1411**B together. The transducer **6211** is coupled between ground and the circuit **6011** in an opposite polarity than transducer **6411**.

On the opposite end of the transmit and receive circuit **6011** is a voice operated transmission (VOX) circuit **6811**. The VOX circuit **6811** detects a transmission signal (Tx) generated by the operator of headset **1211**. When a sufficient Tx signal is detected, the VOX circuit **6811** activates a Radio Frequency (RF) transmit and receive device **7011** to transmit the Tx signal over antenna **7211** to a receiving device. When the Tx signal is not detected, the VOX circuit **6811** enables the transmit and receive device **7011** to receive any incoming receive signals (Rx).

In one example, the transmit and receive device **7011** is a two-way radio or walkie-talkie. However, it should be understood that the transmit and receive circuit **6011** can operate with any two-way communication device **7011**, including but not limited to, cellular telephones, wireless phones, landline telephones, transceivers, walkie-talkies, etc. In the case of a telephone, the VOX circuit **6811** may not be needed.

An Rx signal is input at terminal **7411** of circuit **6011** to op-amps **7811** and **8011**. An Rx level circuit **7711** adjusts the Rx voltage level into op-amps **7811** and **8011**. The output of op-amp **7811** is coupled to the positive terminal of transducer **6211** in headphone **1411**A. The output of op-amp **8011** is coupled to a negative terminal of transducer **6411** in headphone **1411**B. The positive terminal of transducer **6411** is coupled to ground and the negative terminal of transducer **6211** is coupled to ground.

The Rx signal is fed into the op-amps **7811** and **8011** and back out to the transducers **6211** and **6411**. Because the transducers **6211** and **6411** have reversed polarities, a listener will hear a negative Rx signal in one ear and a positive Rx signal in the other ear. In other words, the Rx signals output from the two headphones **1411**A and **1411**B are 180 degrees out of phase. However, it has been discovered that the human brain does not distinguish between the positive and negative Rx signals output by transducers **6211** and **6411**. Thus, any incoming receive Rx signal output from headphones **1411**A and **1411**B sounds exactly the same in both ears of the headphone user. The Rx portion of the signal output from op-amps **7811** and **8011** are in-phase. The two Rx signals fed into the negative and positive terminals of differential amplifier **8211** cancel out.

When the user of headset **1211** talks, a Tx signal is output from transducer **6211** and the same Tx signal is output from transducer **6411**. Because the transducers **6211** and **6411** are in reversed polarity, the two Tx signals output through op-amps **7811** and **8011** are 180 degrees out of phase. Therefore, the two Tx signals at the negative and positive terminals of differential amplifier **8211** are added together doubling the Tx signal (2Tx) at the output of op-amp **8211**.

An interconnect circuit **8411** is used to connect the transmit and receive circuit **6011** to different cellular, cordless and corded telephones **8811**. The interconnect circuit **8411** includes a Field Effect Transistor (FET) **8611** having a gate coupled to an output of op-amp **8211** through a variable resistor **8811**. The Tx signal passes from the output of op-amp **8211** to the gate of FET **8611**. The FET **8611** varies the voltage across the 2.2 K resistor varying the Tx signal delivered to the telephony device **8811**.

The transmit and receive circuit **6011** enables easier and clearer two-way communications. The circuit **6011** can be located in the headset **1211** or can be located in the two-way communication device **8811**.

The transmit and receive circuit **6011** enables the transducers **6211** and **6411** in head phones **1411**A and **1411**B to operate as both microphones for picking up audio signals from the user and also operate as speakers for outputting received Rx signals. When a user of the headset **1211** speaks, audio signals are output through the user's ear canals. These audio signals are converted by the transducers **6211** and **6411** in headphones **1411**A and **1411**B into Tx signals. Because the Tx signals are generated by the headphones, there is no need to mount a separate microphone on a boom in front of the users mouth.

Further, because the audio signals from the user are output from the ear canals and directly into the headphones **1411**A and **1411**B, there is significantly less outside ambient noise that is picked by transducers **6211** and **6411** when operating as microphones. As a result, the user's voice signals comprise a larger and clearer part of the generated Tx signal.

Headphones **1411**A and **1411**B in one embodiment have foam pads that have been found to work exceptionally well in filtering ambient noise from the transceivers. However, any commercially available headset can be adapted to be used with the transmit and receive circuit **6011** including earphones that insert into the user's ear canal. Because no separate microphone boom is required, the full duplex headphones are also less expensive to manufacture and easier to operate.

FIG. **14** shows another embodiment of the headset circuitry. A first headphone or earphone **9411** includes a transducer **9611** that operates as a speaker. A headphone or earphone **9211** includes an electret microphone **9811**. A rubber housing is located between the electret **9811** microphone and a housing for headphone or earphone **9211**.

A plug **1021** includes a tip connection **1041**, ring connection **1061** and a ground connection **1081**. The microphone **9811** is coupled through a switch **1001** to an amplifier circuit **9011**. The output of an amplifier **1101** is coupled through a capacitor to the tip connection **1041**. A variable resistor **1121** varies the gain of amplifier **1101**. The ring connection **1061** is coupled to both switch **1001** and transducer **9611**. The amplifier circuit **9011** and switch **1001** can be located either in the headset **4211** or **4811** or in the device **5411**.

The headset **4211** or **4811** operates as stereo speakers when the device **5411** operates as an audio player. In the audio player mode, an audio signal is received at the ring connection **1061** and fed through wire **1141** to transducer **9611**. The switch **1001** is moved to the position where the received audio signal from wire **1141** is also connected to headphone **9211**. In this configuration, both headphones or earphones **9211** and **9411** operate as speakers.

When the device **5411** is switched over to operating as a two-way communication device, such as a cellular telephone, switch **1001** connects headphone or earphone **9211** to amplifier **1101**. The user of headset **4211** or **4811** talks during the telephone conversation using the cellular phone in device **5411**. The user's voice signals are picked up by the microphone **9811** and output as a transmit Tx signal to amplifier **1101**. The amplifier **1101** amplifies the Tx signal and outputs the transmit signal to the tip connection **1041** of jack **1021**. Any received voice signals from the cellular telephone in device **5411** are received on the ring connection **1061** of jack **1021** and are output to the transducer **9611**.

Thus the headset **4211** or **4811** provides stereo speakers when the device **5411** is being used as an audio player. When the device **5411** is switched over to operating as a two-way communications device, the headphone or earphone **9211** switches over to operating as a microphone. The headphone or earphone **9211** generates the Tx signal from the voice of the user while headphone or earphone **9411** continues to operate as a speaker for outputting Rx signals to the user.

FIG. **15** shows one example of how the communication circuits in FIGS. **8**–**14** are incorporated into an earpiece **60**. This particular configuration is especially effective in high noise environments because the earpiece **60** has a nipple **62** that penetrates into and fits snuggly within the operator's ear canal **70** (FIG. **17**). The nipple **62** includes an umbrella-like shroud **64** made of a soft, flexible material, such as a rubber or plastic, that conforms to the shape of the external auditory canal. The pinnacle of the shroud **64** has an opening **66** that allows air to pass through the shroud **64** and nipple **62** to the transducer **10** within an earpiece housing **68**. A stalk **67** of housing **68** is inserted into the nipple **62** and is made of a hard plastic. The rest of the communication circuit **8** is located either in the earpiece housing **68** or located in the phone that the earpiece **60** is connected with.

FIG. **16** shows a perspective view of the nipple earpiece **60** shown in FIG. **15**. The nipple **62** snaps onto the earpiece housing **68** that houses the transducer **10** and possibly all or a part of the remaining components of the communication circuit **8**.

FIG. **17** shows an expanded view of the earpiece **60** resting within an ear **72** of an operator. This particular illustration shows how the earpiece **60** rests within a pocket of the ear such that the opening **66** in earpiece **60** is oriented in the direction of the external ear canal **70**. The earpiece **60** extends out of the ear and acts as a conduit for a cord **74** carrying the wires from the transducer **10** or communication circuit **8** inside the earpiece.

The earpiece **60** described above provides hands-free full duplex communications without having to use a microphone extension arm. A microphone does not have to be positioned near the mouth since the voice sounds are essentially provided through the ear canal. Also the same transducer **10** is used for both detecting voice signals from the operator while the operator is talking and also for generating audio signals to the operator from audio signals received from a wireless or landline telephone system. Thus, only one earpiece has to be inserted into the ear of the operator.

Multiple transducer housing styles can be used to suit the various preferred choices of use. An earpiece attachment that protrudes outside the ear canal can be used for less noisy environments. Two earpieces can be used, one used as a microphone and one as the ear phone.

The lightweight ear microphones use small miniature electro-dynamics transducers weighing approximately 5 grams or 0.18 oz. to minimize fatigue. The lightweight piezoelectric transducers further improve performance and reduce weight. Lightweight head bands, ear supports, and contoured transducer housings, such as those designed for security personnel, and the hearing impaired, provide snug fit in the outer ear canal.

Applications for the Microphone/Speaker Headset

Referring to FIG. **18**, a microphone/speaker circuit **1000** can be located in the headset **1100** or can be located in the transmit and receive device. Any audio device can be used with the full duplex headphones and circuit **1000**. For example, a landline based telephone **6000**, a cellular telephone **6200**, a wireless telephone **6600** or a walkie-talkie **6400**. The headset **1100** can be utilized with anyone of these devices, or any other device that requires two-way communications.

The transmit and receive circuit **1000** enables the transducers **1900** and **1500** in head phones **1200** and **1400** to operate as both microphones for picking up external Tx audio signals and speakers for outputting received Rx signals. When a user **5200** of the headset **1100** speaks, audio signals **5600** are output through the user's ear canals **5400**. These audio signals **5600** are converted by the transducers **1500** and **1900** in headphones **1200** and **1400** into Tx signals.

Because the audio signals from the user **5200** are output from the ear canals **5400** and directly into the cups of headphones **1200** and **1400**, there is significantly less outside ambient noise that is picked by transducers **1900** and **1500**. For example, the noise from a radio **5000** is significantly filtered user **5200**'s voice signals **5600**. As a result, the user's voice signals **5600** comprise a larger and clearer part of the generated Tx signal.

Headphones **1200** and **1400** have foam pads **7000** that have been found to work exceptionally well in filtering ambient noise from the transceivers. However, any commercially available headset can be adapted to be used with the transmit and receive circuit **1000** including earpieces that insert into the ear canal. Because no separate microphone boom is required, the full duplex headphones are also less expensive to manufacture and easier to operate.

FIG. **19** shows a single earphone type headphone **1811**. The earphone **1811** includes a transducer that operates as both a microphone and a speaker as described above. The earphone **1811** is attached to a cord **3411**. An opposite end of the cord **3411** is connected to a retractable take-up reel **3811**. The take-up reel **3811** is located inside of a cellular telephone **3211** or any other two-way communication device.

The cord **3411** is pulled out from reel **3811** as far as needed for a user to insert earphone **1811** into the user's ear canal. The reel **3811** includes a latch (not shown) that holds the cord at the extended position. When the user is finished with the earphone **1811**, the cord is pulled further out from the reel **3811**. The latch then releases the reel **3811** and allows the reel **3811** to retract the cord **3411** back into the cellular telephone. Alternatively, a button on cellular telephone **3211** can be used to release the reel **3811** allowing retraction of cord **3411**.

In an alternative embodiment, an earphone **3611** includes a wireless transceiver **3711**. A transducer in earphone **3611** converts a user's voice into electrical Tx signals. A transceiver **3711** in the earphone **3611** transmits the Tx signals wirelessly to another transceiver **4011** in cellular telephone **3211**.

Rx signals received by the cellular telephone **3211** from another caller are transmitted by transceiver **4011** to transceiver **3711** in earphone **3611**. The transducer in earphone **3611** then converts the Rx signals into audio signals. The wireless signals transmitted and received by the transceivers **4011** and **3711** use any frequencies to transmit the Tx and Rx signals. For example, the same frequencies and circuitry used by wireless telephones for wireless Tx and Rx transmission and reception.

FIG. **20** shows a device **5411** that includes both a cellular telephone **5611** and an audio player **5811**. The audio player **5811** can be any one or any combination of audio playing devices such as a CD player, MD player, MP3 player, radio, cassette tape player, etc. The cellular telephone **5611** can alternatively be a two-way radio or any other type of two-way communication device.

The headsets **4211** and **4811** operate as stereo headphones when the device **5411** is used as an audio player and operate as a separate microphone and speaker when the device **5411** is used as a telephone as previously described in FIG. **14**.

Headphone **4411** in headset **4211** or earphone **5011** in headset **4811** operates as a microphone when the device **5411** is used as a cellular telephone. Headphone **4411** or earphone **5011** operates as a speaker when the device **5411** is operating as an audio player. Headphone **4611** or earphone **5211** operates as a speaker for both the cellular telephone **5611** and audio player **5811**.

Since headphone **4411** and earphone **5011** each operate as either a microphone or a speaker, the headsets **4211** and **4811** provide stereophonic sound when the device **5411** is using the audio player **5811**. When the device **5411** switches over to using the cellular telephone **5611**, the headphone **4411** and the earphone **5011** automatically switch over to operating as microphones. The transducer in headphone **4411** or earphone **5011** picks up the voice signals coming from the user's ear canal and converts those voice signals into a Tx signal that is sent to the cellular telephone **5611** for transmission over a cellular telephone channel. When the device **5411** is switched back to operating audio player **5811**, the headphone **4411** or earphone **5011** switches back to operating as a speaker.

FIG. **21** shows headsets **2211** and **2411** that each has one headphone **2411** or earpiece **2611**, respectively, that operates as a microphone and another headphone **2611** or earpiece **2811** that operates as a speaker. The headsets **2211** and **2411** are shown being used with a cellular telephone **3011** but can be used with any two-way communications device, such as a two-way radio, wireless telephone or landline telephone.

FIG. **22** shows a headset **1211** having two headphones **1411** that each operate as both a speaker and a microphone. The headphone is connected to a two-way communications device **2011**, such as a two-way radio, telephone, cellular phone, etc. Headset **1511** includes a single headphone **1611** that operates as both a microphone and speaker. A single earphone type headset **1711** includes an earphone **1811** that includes a transducer that operates as both a microphone and speaker as described above.

FIG. **23** shows another embodiment of a headset **1201** that can be used with the dual telephone/audio player device **5411** or any other two-way communications device. Headphones **1211** include transducers **1221** that serve as stereo speakers for outputting audio signals from the audio player in device **5411**. The transducers **1221** also output any received Rx signals from the cellular telephone in device **5411**.

Two separate microphones **1241** are located on the outside of the headphones **1211** and pickup audio signals while the user of headset **1201** is speaking. The microphones **1241** generate a transmit Tx signal that is output to the cellular telephone in device **5411**. When the device **5411** operates as an audio player, the microphones **1241** are disabled.

The microphones **1241** and speakers **1221** are connected to a jack **1261** that plugs into device **5411**. Any combination of microphones **1241** and speakers **1221** can be used. For example, the headset **1201** may have two speakers **1221** and only one microphone **1241** located on the outside of one of the headphones **1211**. Alternatively, there may only be one headphone or earphone with only one microphone **1241** and only one speaker **1221**. Whatever the configuration, the headset **1201** provides two-way communications when the device **5411** is operating as a cellular telephone and outputs mono or stereo sound when the device **5411** operates as an audio player.

Full Duplex Headset with Voice Recognition System

Referring to FIG. **24**, a headset **1822** includes two headphones **1422**. The headphones **1422** can both operate as microphones, or can both operate as microphones/speakers, or one headphone **1422** can operate as a microphone while the other headphone **1422** operates as a speaker. The headset **1822** can use any of the full duplex circuits described above or any headset that includes a microphone that converts voice signals **2222** into electrical signals. The headphones **1422** each include a transducer **1622** that operates in one mode of operation as a microphone. In one embodiment, the transducer **1622** is a miniature piezoelectric, electret type, transducer. However, it should be understood that any type of transducer can be used.

While the operator **1222** is talking, the transducers **1622** detect the voice signals **2222** that pass out through the ear canals **2022** inside the head of operator **1222**. The transducers **1622** convert the voice signals **2222** into electrical transmit Tx signals that are coupled through cables **2822** to a computer **3022**.

By locating one or more microphones **1622** inside one or more of the headphones **1422**, the voice signals **2222** from the operator's ear canal **2022** can be detected while at the same time filtering out unwanted ambient noise. Other unwanted noise from the user **1222**, such as breathing noises, are also less of a problem because the microphone **1622** is no longer located on a boom underneath the users noise.

Software and a processor in the computer **3022** operate as a Voice Recognition System (VRS) **2922** and attempts to identify the words represented by the electrical Tx signals from cable **2822**. The audio signals are interpreted by the VRS **2922** and displayed as words **2622** on the computer screen **2422**. The VRS **2922** prevents the operator **1222** from having to manually type the words into the computer with keyboard **3222**. The headset **1822** can be used for any Voice Recognition System that detects voice signals. Because, there is less noise in the Tx signals, the VRS **2922** is more likely to correctly identify the words coming from the operator's voice signals.

The headsets described in the references cited above can operate as both speakers that output received Rx signals to a user and microphones that transmit Tx signals from the operator's ear canal back to another endpoint. If the circuitry in headset **1822** operates as both a microphone and a speaker, the headset **1822** can be used with other applications other than VRS **2922**. For example, the headset **1822** can also be used with any two-way communication device or application such as a cellular telephone, two-way radio, wireless phone, etc. The headset **1822** can also be used as a speaker for receiving audio signals from any CD, MD, MP3 or tape player.

For example, by selecting a different software application on the computer **3022**, the computer can activate a Voice Over Internet Protocol (VoIP) phone application **3122**, CD player, MD player, IP radio player, MP3 player **3322**, or any other type of communication or audio playback application. The headset **1822** then not only generates the Tx signals output from the operator **1222** to the VRS application **2922** or VoIP application **3122** but also receives the Rx signals from any one of the sound playback applications referred to above.

It should also be understood that the microphone generating the Tx signals for the VRS application **2922** can be located inside any earphone, headphone, earpiece or any device or apparatus that goes inside or partially or fully covers the operator's ear or otherwise enables detection of voices signals from in the operator's ear canal **2022**.

FIG. **25** shows another embodiment of the invention that includes a first transducer **5622** that generates a Tx signal **6022** from the audio signals **4422** output from the ear canal **4222** of operator **3822**. A circuit **4622** as described in any one of the full duplex circuits above increases the Signal to Noise Ratio of the Tx signal **6022** and then outputs the Tx signal on line **4822**. The circuit **4622** in some embodiments of the referenced applications also allows the transducer **5622** to operate as a speaker.

While the transducer **5622** is operating as a microphone, it may be desirable to feedback the Tx signal to a speaker **5422**. The Tx signal **6222** is output from speaker **5422** as voice signals **5022**. This provides positive acknowledgement back to the operator **3822** that the voice signals **4422** are being successfully detected and output by transducer

5622 and circuit 4622. The feedback Tx signal 6222 may be further amplified by an amplifier 5222 before being fed to speaker 5422.

Loopdown and Looparound Headsets

FIGS. 26 and 27 show a loopdown headset 1433 that includes two earpieces 1633 for attaching to ears of an operator 1233. A band 2433 has opposite ends 1533 that connect to the two earpieces 1633. Earpieces 1633 include ear cups 2033 that insert into ear canals 2833 and 3033. A middle section of the band 2433 extends downwardly below a chin 2633 of a headset operator 1233. The band 2433 in one embodiment is made of a semi-rigid piece of plastic or metal.

While earpiece 1633 is shown with cups 2033, the shape of the strap and other aspects of the invention can be used with other types of earpieces. For example, the earpiece can comprise an earmuff style where the earpiece covers the entire outside ears of the operator and includes a foam pad that rests against the sides of the operator's head. Alternatively, a disc style earpiece can be used that may include a form pad that rests directly against the outside of the operator's ear without inserting directly into the ear. Other types of ear plugs or ear plunger style earpieces can also be used that insert directly into the ear canal of the operator.

In one embodiment of the headset 1433, a transducer 2133 operates as a microphone and is located either in one of the ear cups 2033 or in the main body section 2333 of earpiece 1633. The transducer 2133 is used to detect sound waves and bone conduction that is emitted through the ear canal 2833 when the operator 1233 is talking. The transducer 2133 converts the sound waves into electrical transmit signals that are output through a wire 2533 that extends inside of the band 2433. Another transducer 2233 operates as a speaker and is located either in another one of the cups 2033 or in the main body 2333 for another one of the earpieces 1633. The transducer 2233 converts electrical receive signals from wires 2533 into sound waves that are output into an opposite ear canal 3033 of the operator 1233. Any of the alternative full duplex circuits described above can also be used.

The side view of the loopdown headset 1433 in FIG. 27 shows how the ends 1533 of band 2433 extend in a slightly forward direction 3233 toward the front face of operator 1233. The middle potion of the band 2433 then loops in a downward direction 3433 underneath the chin 2633 of operator 1233. The ends 1533 of the band 2433 curve forward to extend in front of the earlobes 3633 of the operator 1233. This forward bend and downward loop in the band 2533 in combination with the position of the cups 2033 provide superior fit and comfort of the earpieces 1633 in the ears of the operator 1233. The forward curving ends 1533 also prevent the band 2433 from rubbing against earrings that the operator may be wearing.

FIGS. 28 and 29 show in further detail the position of cups 2033 in relationship to the forward and then downward direction of band 2433. The cups 2033 each have a front face 3833 that extends substantially along a vertical plane 4033. The opposite ends of the band extend longitudinally along a line 4233 at an angle anywhere between 5 degrees to 45 from the vertical plane 4233.

Referring to FIGS. 26–29, the headset 1433 is pulled slightly outward at opposite ends 1533 by the operator. The head of the operator is then slid between the opposite ends 1533. The elastically deformable band 2433 then retracks toward its original position as the earpieces 1633 are inserted into ears of the operator. In the attached position, the opposite ends 1533 extend forward and then downward from the ears of the user.

The transducer microphone 2133 detects sound waves coming from the first ear canal 2833 while the operator 1233 is speaking. Because, the ear cup 2033 is located inside the ear canal 2833, there is little or no pickup of ambient noise. The speaker transducer 2233 converts electrical receive signals into sound waves that are output into the second ear canal 3033 of the operator 1233.

FIG. 30 shows a perspective view, FIG. 31 shows a top view, and FIG. 32 shows a side view for another embodiment of the invention. A headset 5033 includes earpieces 5233 and a band 5633. The earpieces 5233 include cups 5833 similar to the cups 2033 shown in FIG. 26. The opposite ends 6033 of the band 5633 extend from the earpieces 5233 in a forward direction and then loop underneath ears 6633 of the operator.

A middle portion 6233 of the band 5633 extends back around a backside of the neck of the operator 6433. This provides the additional advantage of obscuring the middle portion 6233. For example, long hair or a shirt or coat may hide a portion of the band 5633. This provides a more aesthetically appealing look for the operator 6433. In addition, the band 5633 remains out of reach of others. For example, if operator 6433 was holding a child, the child could not reach up and grab the band 5633 since it is positioned behind the neck.

Again the forward and then downward direction of opposite ends 6033 of the band provide superior comfort and retention of the cups 5833 inside the operators ears. In addition, because the ends 6033 loop underneath the ear 6633, the band 5633 will not rub up against earrings or other article that may be attached to the ears 6633 of the operator 6433.

FIG. 33 is a schematic diagram showing one embodiment of the full duplex circuitry that can be located in either the headset 1433 shown in FIG. 26 or the headset 5033 shown in FIG. 30. The circuitry includes a speaker circuit 1003 and a microphone circuit 1023. Each circuit has two electrical terminals, with one serving as the common or "ground" node. A pair of wires 1043, 1063 and 1083, 1103 are connected to these terminals, and are ultimately joined in a single cord terminating in a connector plug 1143. The wires connected to the ground node 1043, 1083 are joined together and terminate at the sleeve connection 1123 of plug 1143. The wire connected to the opposite terminal of the speaker circuit 1003 is connected to a ring portion 1163 of the plug 1143. On the other side of the headset, the wire 1103 from the microphone circuit 1023 is connected to the tip portion 1183 of the plug 1143.

The speaker circuit 1003 contains a transducer 1013 that converts an electrical signal into an audio output. The microphone circuit 1023 contains a transducer 1033 that converts an audio input into an electrical signal which is communicated to a telephony device via the wires 1083, 1103. Any of the other circuits described above can also be used instead of the circuitry shown in FIG. 33.

A filter circuit 1203 includes a capacitor and an zenor diode that are coupled in parallel across the wires 1083 and 1103. The capacitor in one implementation is approximately 33 Pico farads. The filter circuit 1203 filters out selected low frequency noise from the electrical transmit signal output by the microphone circuit 1023.

The circuitry described above can use dedicated processor systems, micro controllers, programmable logic devices, or microprocessors that perform some or all of the mail notification operations. Some of the operations described above may be implemented in software and other operations may be implemented in hardware.

For the sake of convenience, the operations are described as various interconnected functional blocks or distinct software modules. This is not necessary, however, and there may be cases where these functional blocks or modules are equivalently aggregated into a single logic device, program or operation with unclear boundaries. In any event, the functional blocks and software modules or described features can be implemented by themselves, or in combination with other operations in either hardware or software.

Having described and illustrated the principles of the invention in a preferred embodiment thereof, it should be apparent that the invention may be modified in arrangement and detail without departing from such principles. Claim is made to all modifications and variation coming within the spirit and scope of the following claims.

The invention claimed is:

1. An audio device, comprising:

an earpiece having a transducer that converts an input audio signal from a user into a transmit signal and also converts a receive sianal received from an external device into an audio output sianal intended for listening to by the user, the receive signal including transmit signal components;

a full duplex mode circuit coupled to the transducer including:

a first amplifier having a first input coupled to a first terminal of the transducer and a second input receiving a receive signal with reduced transmit signal components, wherein the first amplifier outputs a combined output signal that includes the transmit signal and the receive signal with the reduced transmit sianal components; and

a second amplifier having a first input coupled to ground and a second input coupled to the same receive signal with the reduced transmit signal components received by the first amplifier, wherein the second amplifier outputs the receive signal with the reduced transmit signal components; and

a digitall signal processing system that isolates the transmit signal from the receive signal, including;

a first input receiving the combined output signal from the first amplifier;

a second input receiving the receive signal from the external device having the transmit signal comnonents;

an output outputting the receive signal with the reduced transmit signal components to the first and second amplifiers: and

a third input receiving the receive signal with the reduced transmit signal components back from the second amplifier.

2. The audio device of claim **1**, wherein the digital signal processing system comprises:

a first analog to digital (A/D) converter converting the combined output signal received at the first input into a digital combined output signal;

a second A/D converter converting the receive signal from the external device received at the second input into a digital receive signal with transmit signal components; and

a third A/D converter converting the receive signal with the reduced transmit signal components at the third input into a digital receive signal with reduced transmit signal components.

3. The audio device of claim **2**, wherein the digital signal processing system further comprises:

a receive adaptive phase canceller shifting the phase of the digital receive signal with the reduced transmit signal components; and

a first adder summing the phase shifted digital receive signal with the reduced transmit signal components and the digital combined output signal to cancel the digital receive signal with the reduced transmit signal comnonents from the digital combined output signal and outputting a digital transmit signal.

4. The audio device of claim **3**, wherein the digital signal processing system further comprises:

a transmit adaptive phase canceller shifting the phase of the digital transmit signal outputted from the first adder; and

a second adder summing the phase shifted digital transmit signal and the digital receive signal from the external device with transmit signal components to cancel the transmit signal components from the digital receive signal from the external device and outputting a receive signal with reduced transmit signal components.

5. The audio device of claim **4**, wherein the digital signal processing system further comprises:

a first digital to analog converter converting the digital transmit sianal into an analog transmit signa; and

a second D/A converter converting the receive signal having reduced transmit sianal comnonents into an analog receive signal.

6. A method for providing full-duplex communications in an earpiece, comprising:

convening an audio input into an analog transmit signal in an interface circuit in the earpiece;

receiving an analog receive signal intended for a user from an external device, the receive signal having transmit signal components, in a digital signal processing system;

outputting a receive signal having reduced transmit signal components from the digital signal processing system to the interface circuit in the earpiece;

converting the receive signal having reduced transmit signal comnonents into an audio output in the interface circuit in the earpiece;

feeding the same receive signal having reduced transmit signal components outputted to the interface circuit back to the digital signal processing system;

generating a combined output signal that includes the transmit signal and the receive signal having reduced transmit signal components; and

cancelling the receive signal having reduced transmit signal components from the combined output sianal in the digital signal processing system.

7. The method according to claim **6** including using a same transducer in the interface circuit to convert the audio inputs into the analog transmit signal and convert the analog receive signals into the audio output.

8. The method according to claim **6**, wherein cancelling the receive signal having reduced transmit signal components from the combined output signal comprises:

phase compensating a digital receive signal having reduced transmit signal components;

applying the phase compensated receive signal having reduced transmit signal components to a combined digital output signal to cancel the receive signal having reduced transmit signal components from the combined digital output signal; and

outputting a digital transmit signal.

9. The method according to claim **8**, wherein outputting the receive signal having reduced transmit signal components from the digital signal processing system comprises:

phase compensating the digital transmit signal; and

applying the phase compensated transmit signal to the receive signal received from the external device having transmit signal components to cancel the transmit signal components from the receive signal received from the external device.

10. An audio device, comprising:

first and second earpieces, each having a transducer for converting an audio input into an electrical transmit signal and converting an analog receive signal received from an external device and intended for outputting to a user into an audio output, wherein the first transducer operates as a speaker and the second transducer operates either in a microphone mode or in a speaker mode;

a switching circuit adapted to select the operational mode of the second transducer; and

a full-duplex transmit and receive circuit, comprising:

a first amplifier having a first input coupled to the positive terminal of the transducer in the first earpiece and an output coupled to a transmit signal output;

a second amplifier having a first input coupled to the negative terminal of the transducer in the second earpiece and an output coupled to the transmit signal output; and

a third amplifier coupled between the outputs of the first and second amplifiers and the transmit signal output.

11. An audio device according to claim **10** wherein the full-duplex transmit and receive circuit outputs a first receive and transmit signal out of phase with a second receive and transmit signal.

12. An audio device according to claim **11** wherein the full-duplex transmit and receive circuit combines the first and second receive and transmit signal.

13. An audio device according to claim **12** wherein the full-duplex transmit and receive circuit cancels the receive signal in the combined first and second receive and transmit signals and increases the transmit signal in the combined first and second receive and transmit signals.

14. An audio device according to claim **10** wherein the full-duplex transmit and receive circuit includes a level control circuit maintaining a receive signal at a constant level.

15. An audio device according to claim **14** wherein the level control circuit includes:

an op-amp including an input that monitors a voltage level of the receive signal;

a transistor circuit activated by the op-amp when the receive voltage rises above a preselected value, the transistor circuit when activated pulling down the voltage level to the preselected value.

16. An audio device according to claim **14** wherein the level control circuit includes a manually adjustable resistor circuit.

17. An audio device according to claim **10** including a switching circuit for switching the full-duplex transmit and receive circuit and the transducers into operating as a one-way speaker device.

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